

図 1

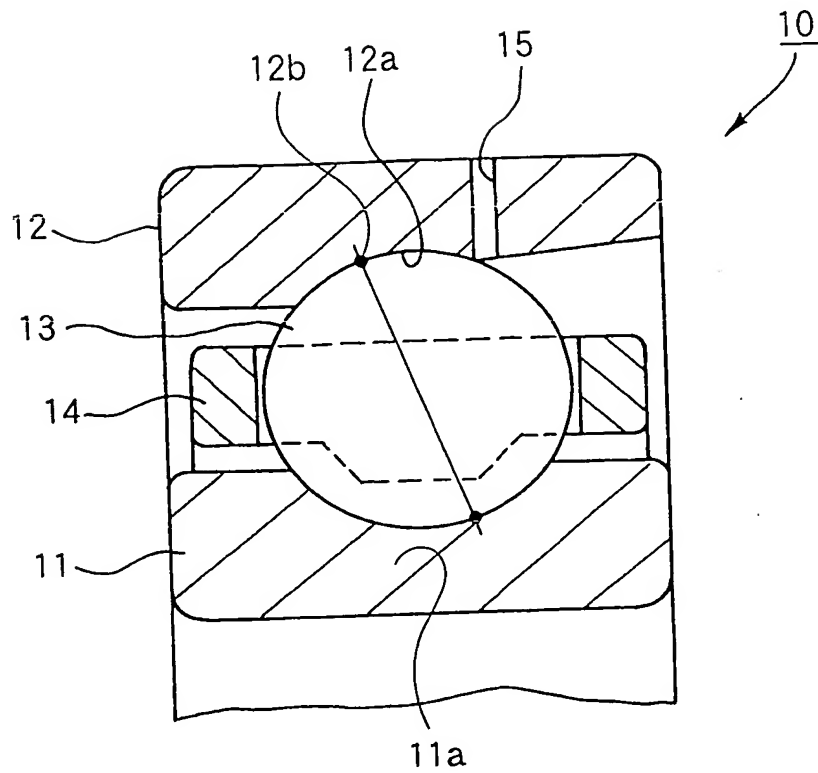


図 2

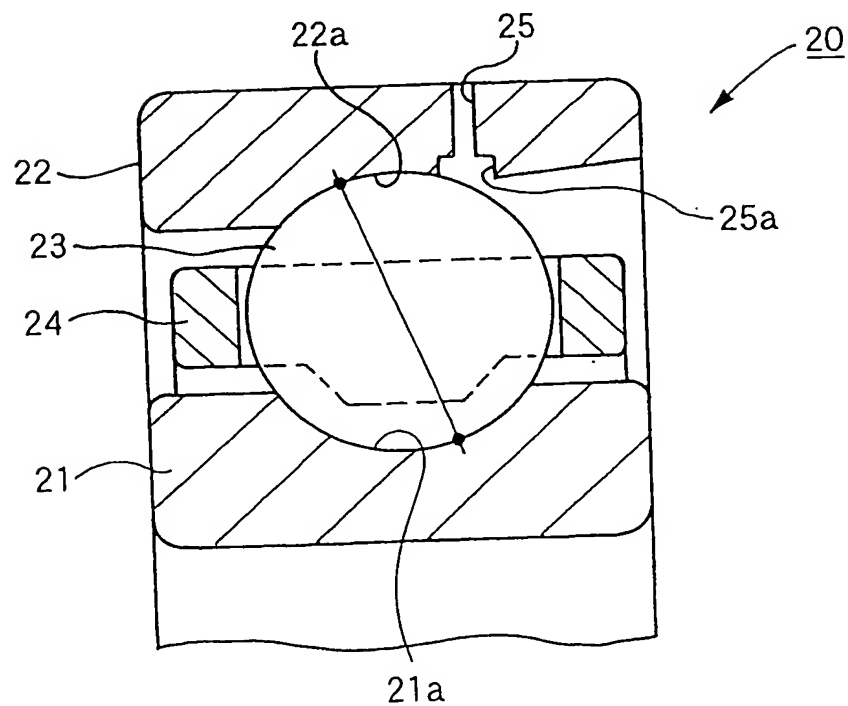


図 3

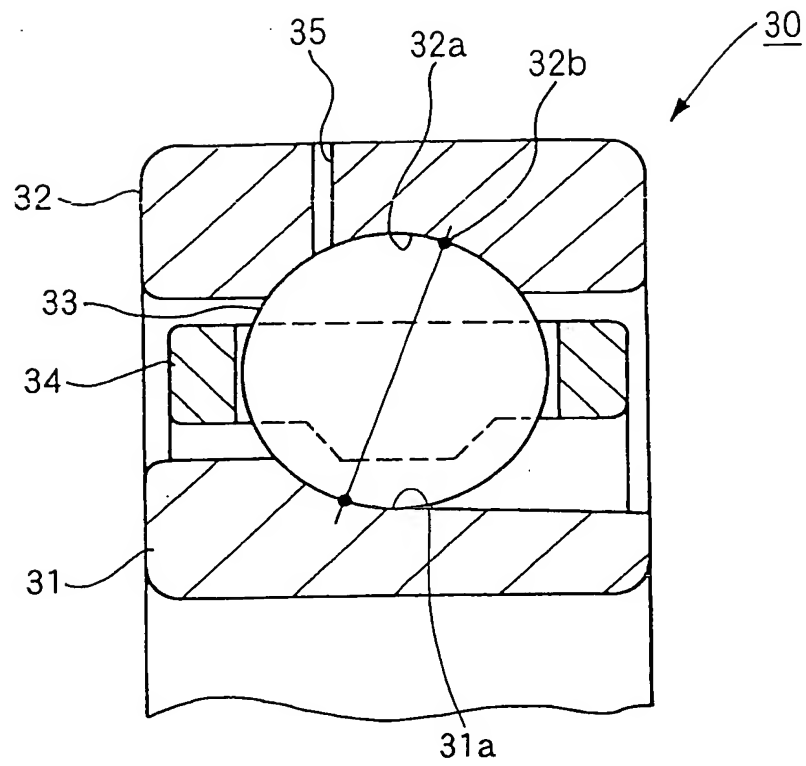


図 4

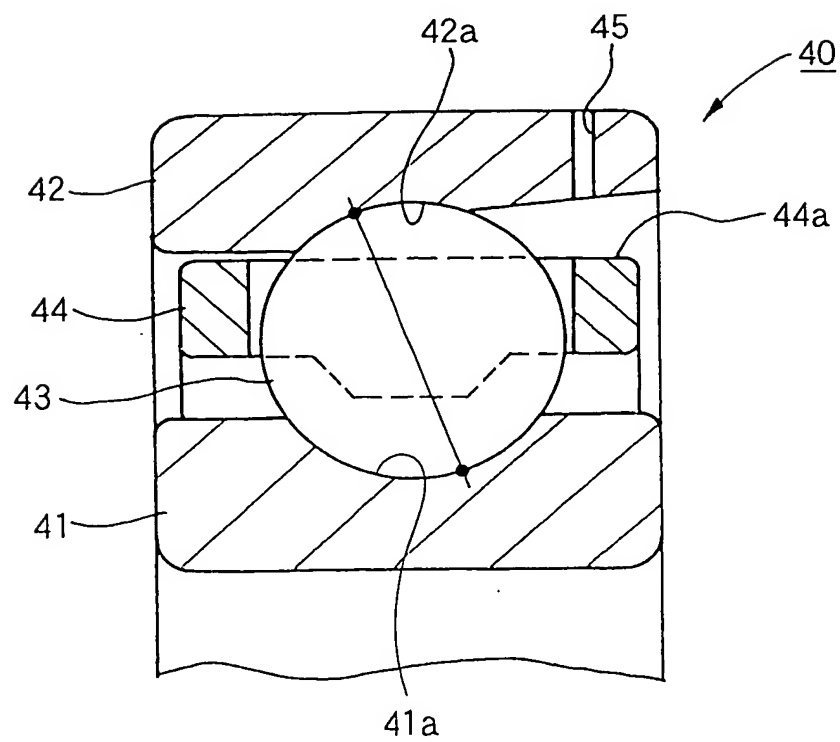


図 7

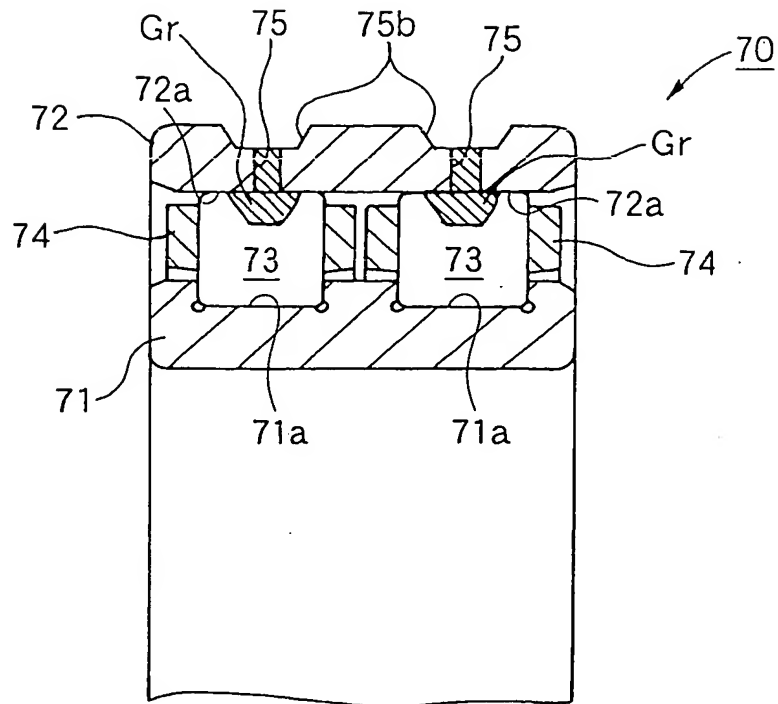


図 8

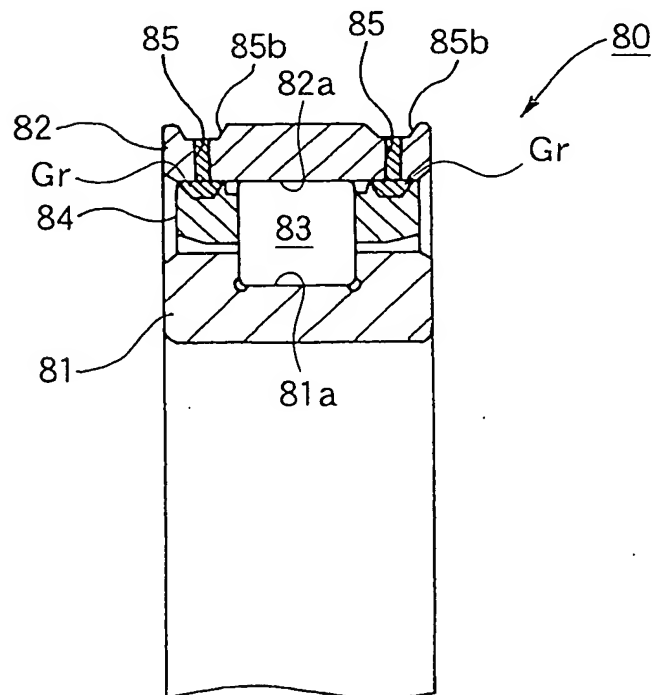


図 9

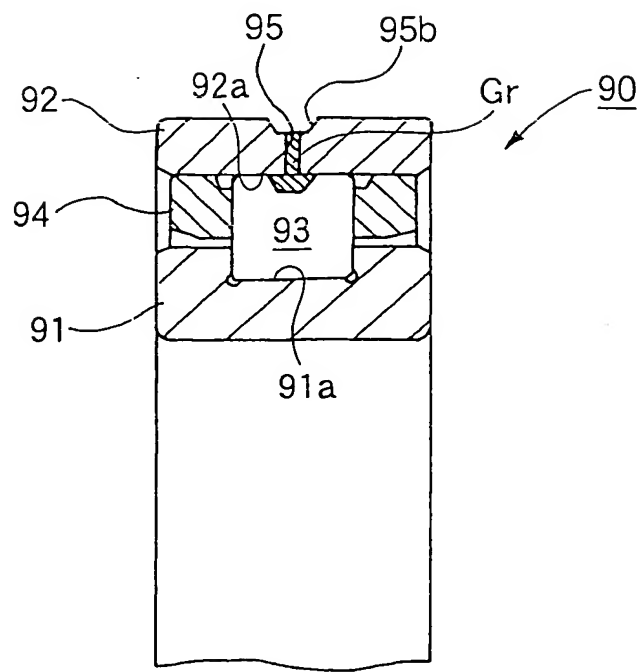


図 10

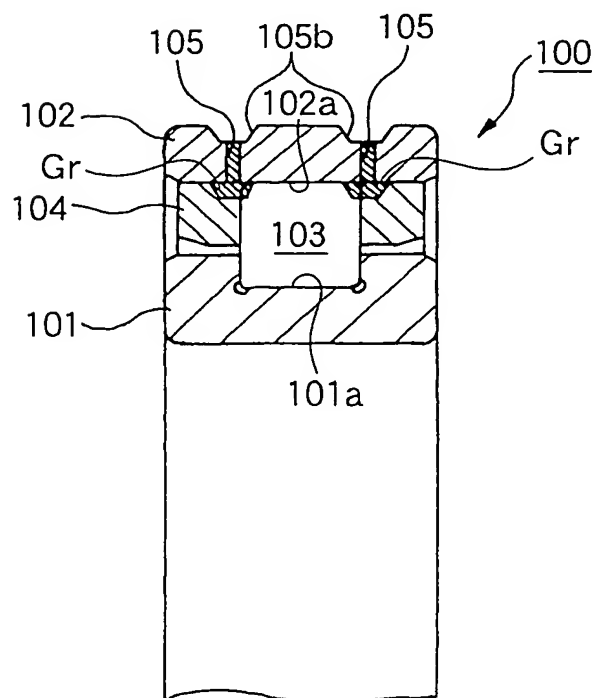


図 11

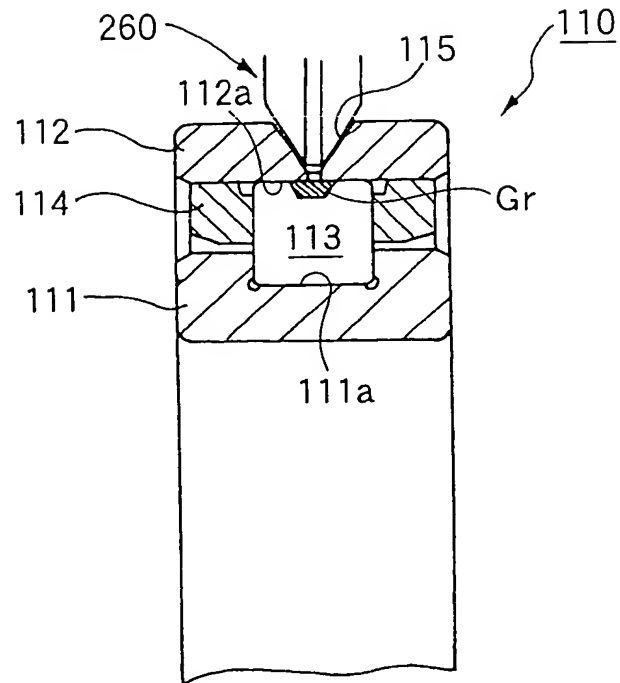


図 12

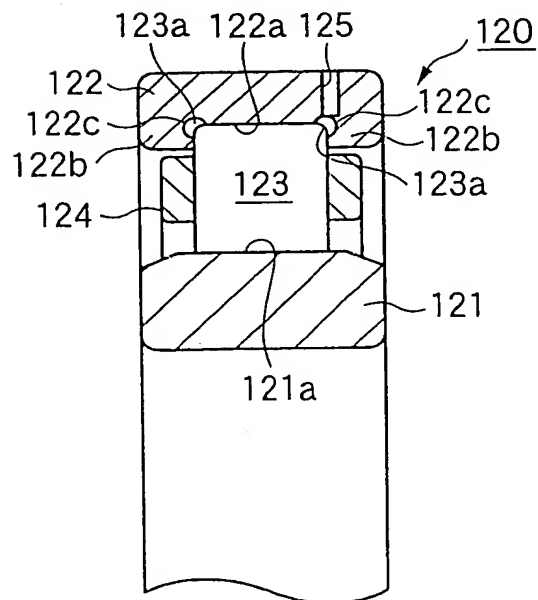


図 13

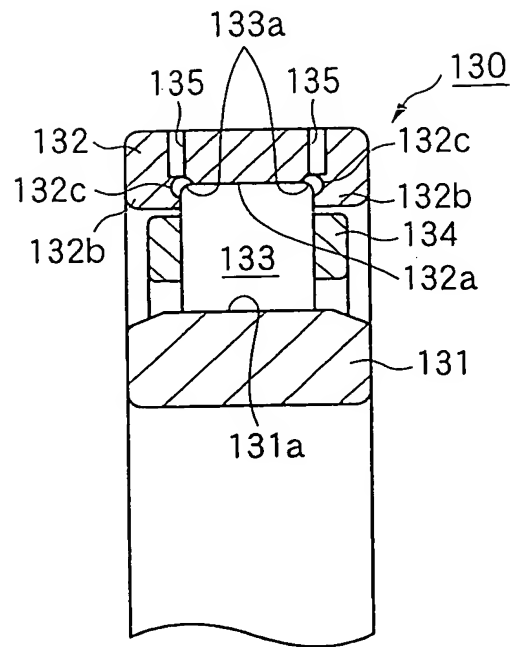


図 14

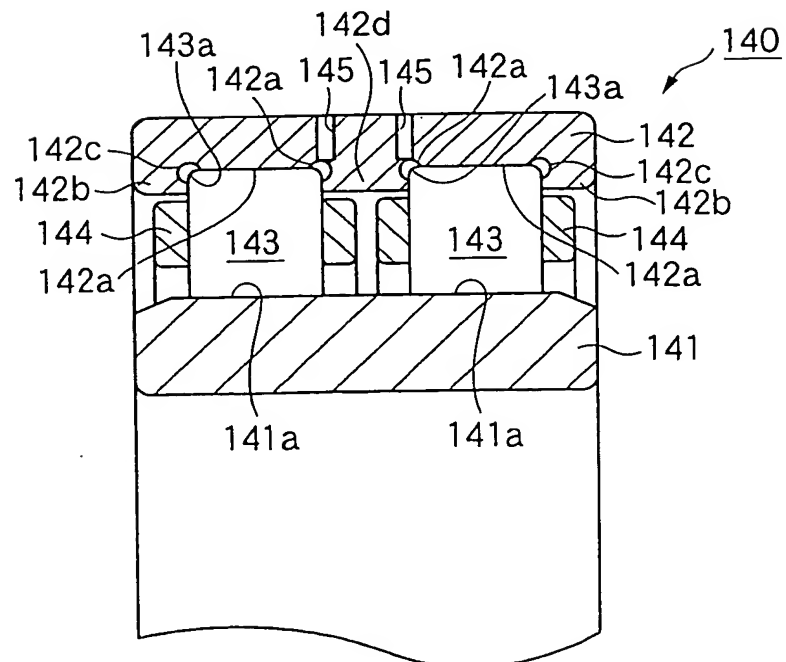


図 15

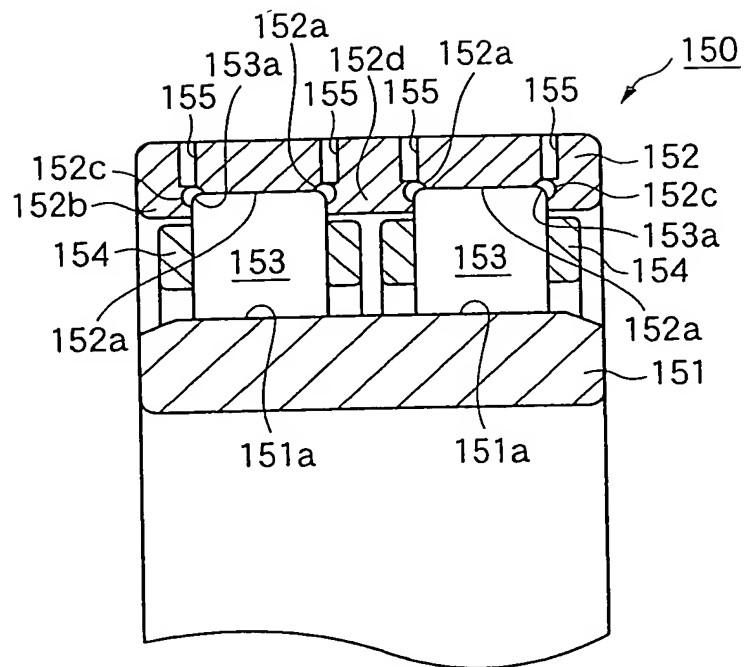


図 16

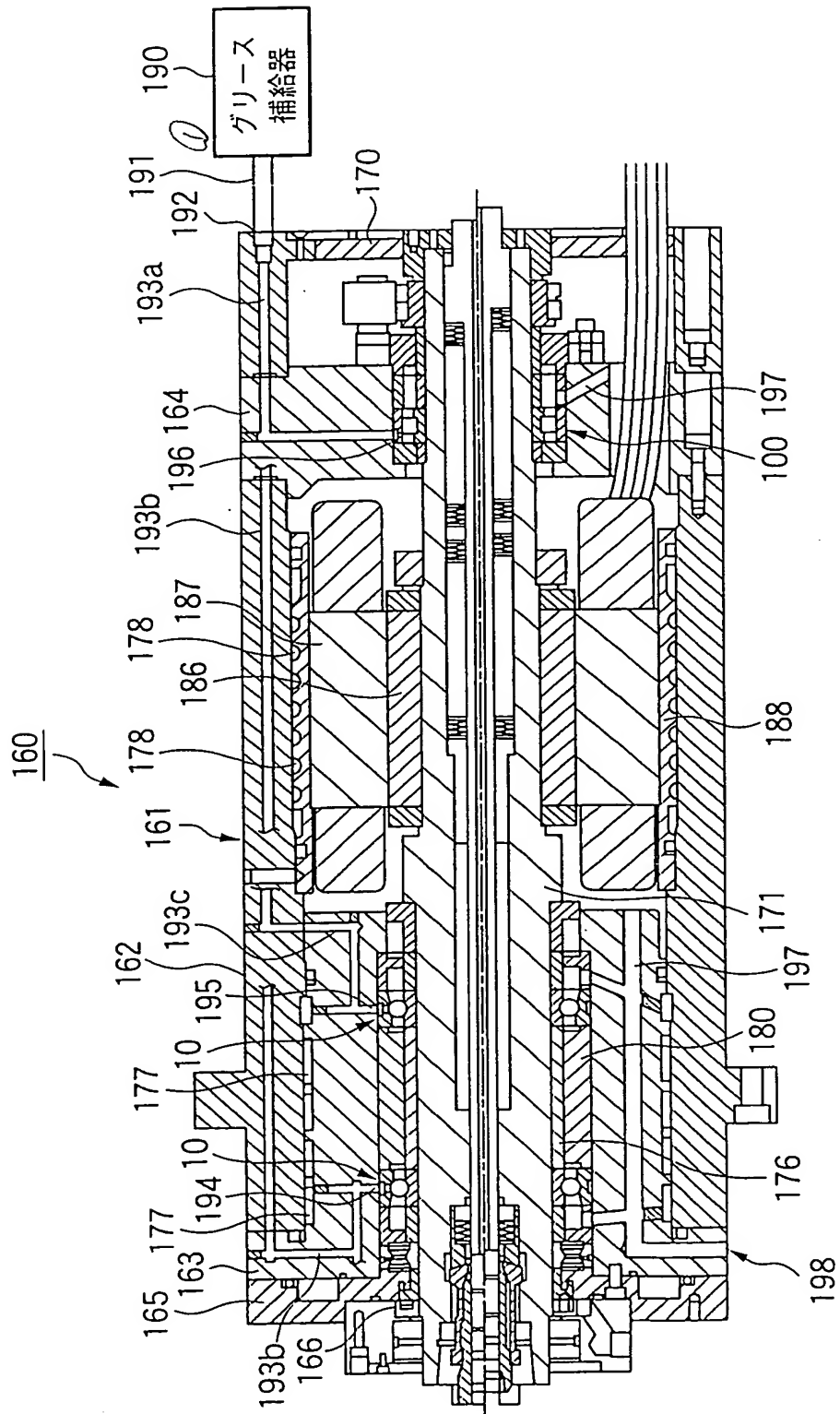


図17

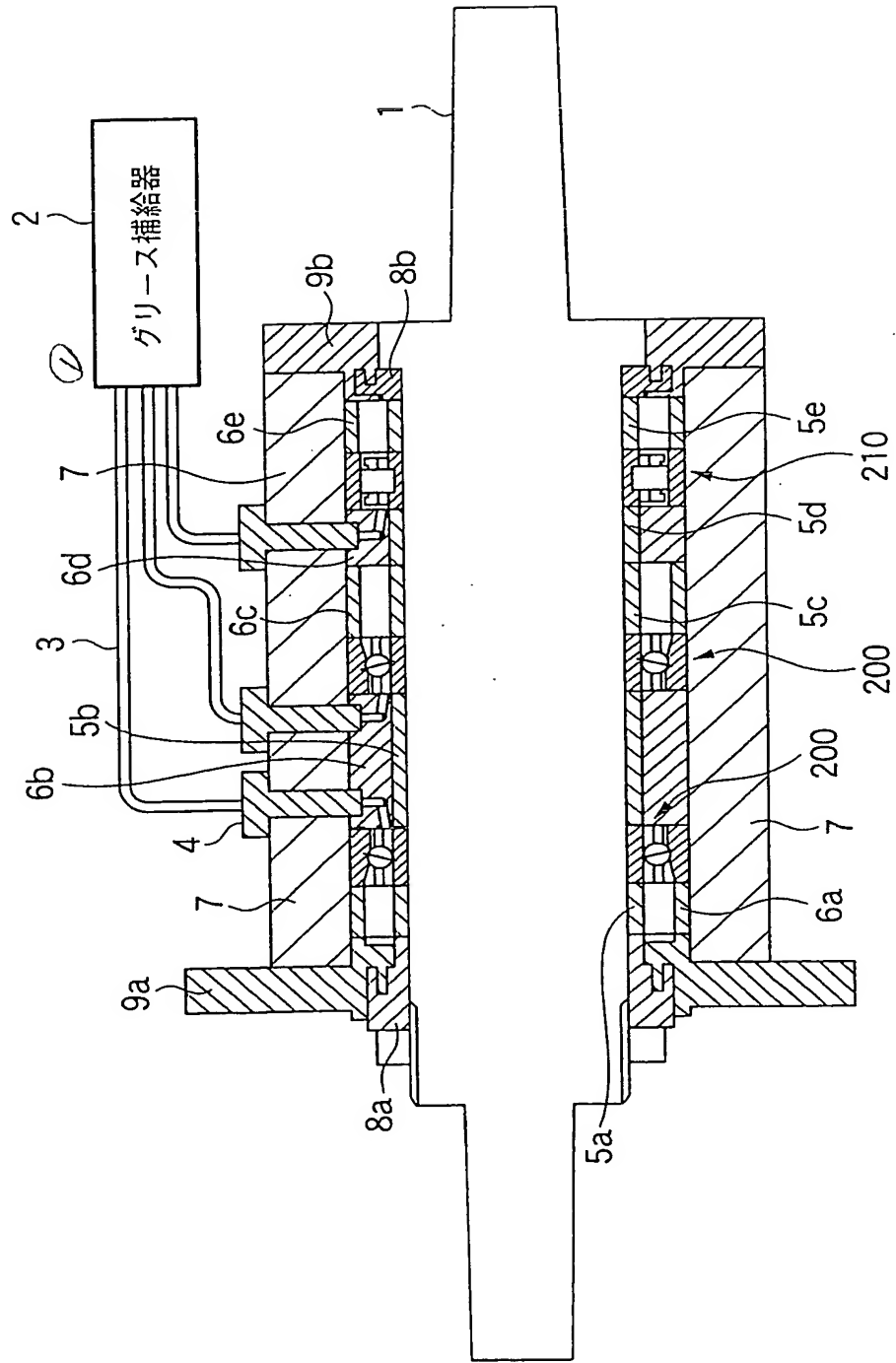


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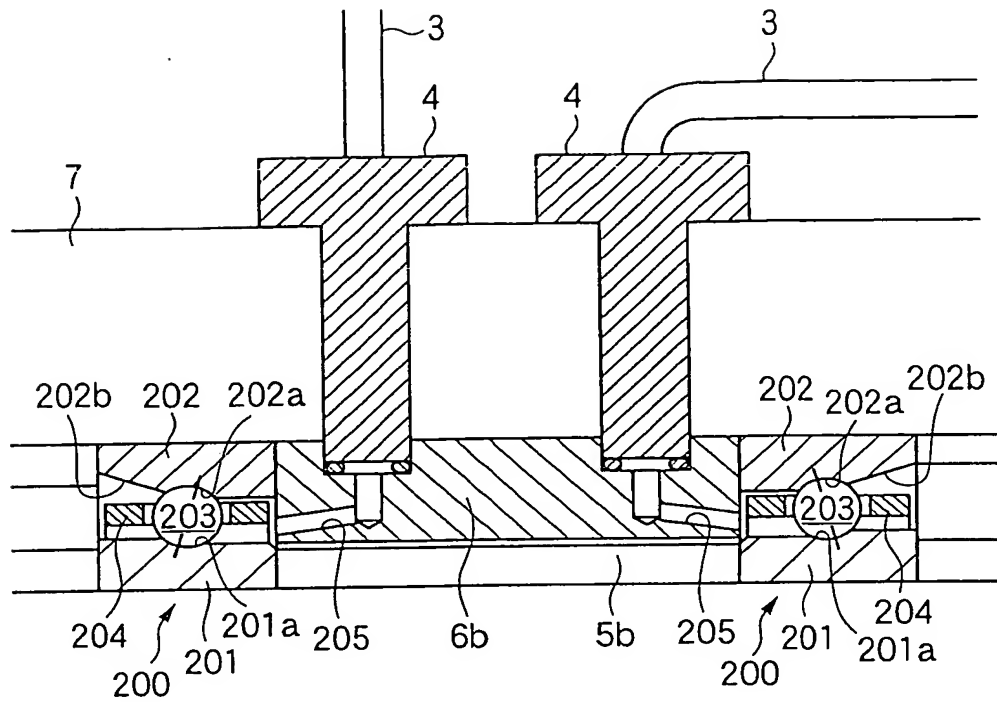


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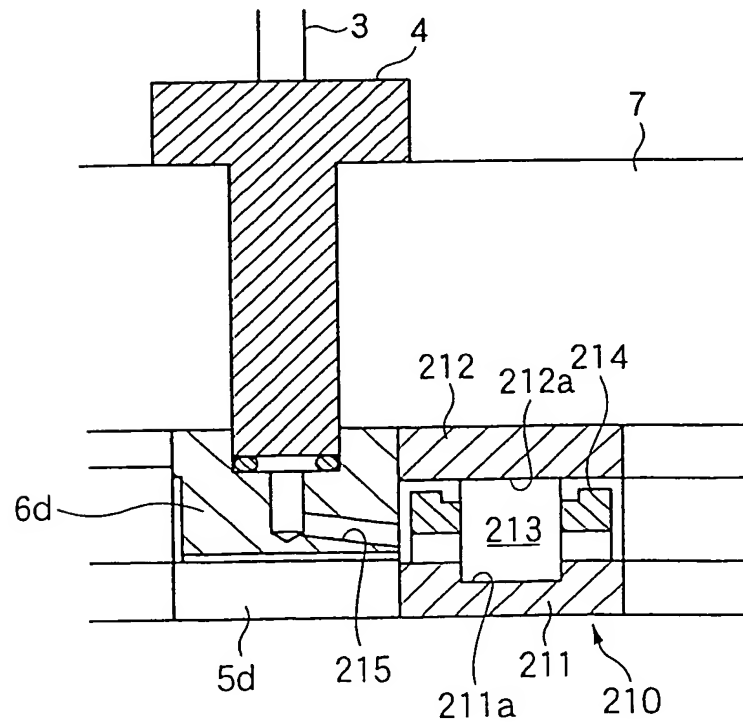


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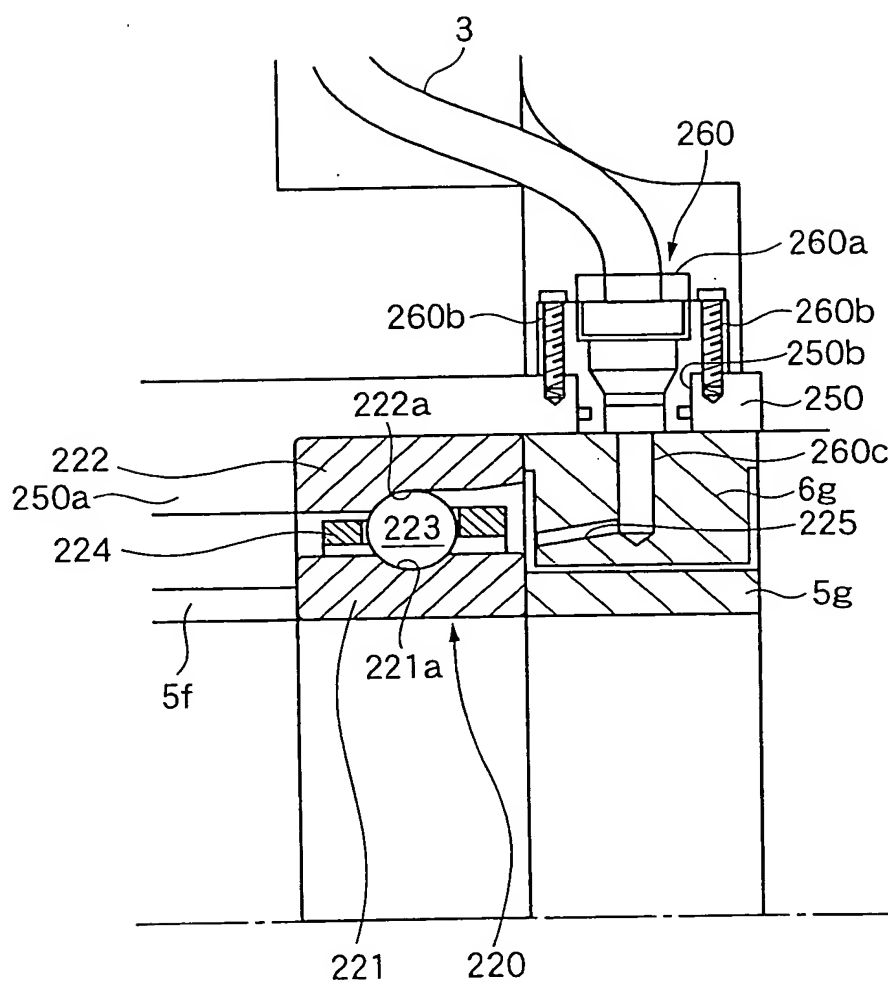


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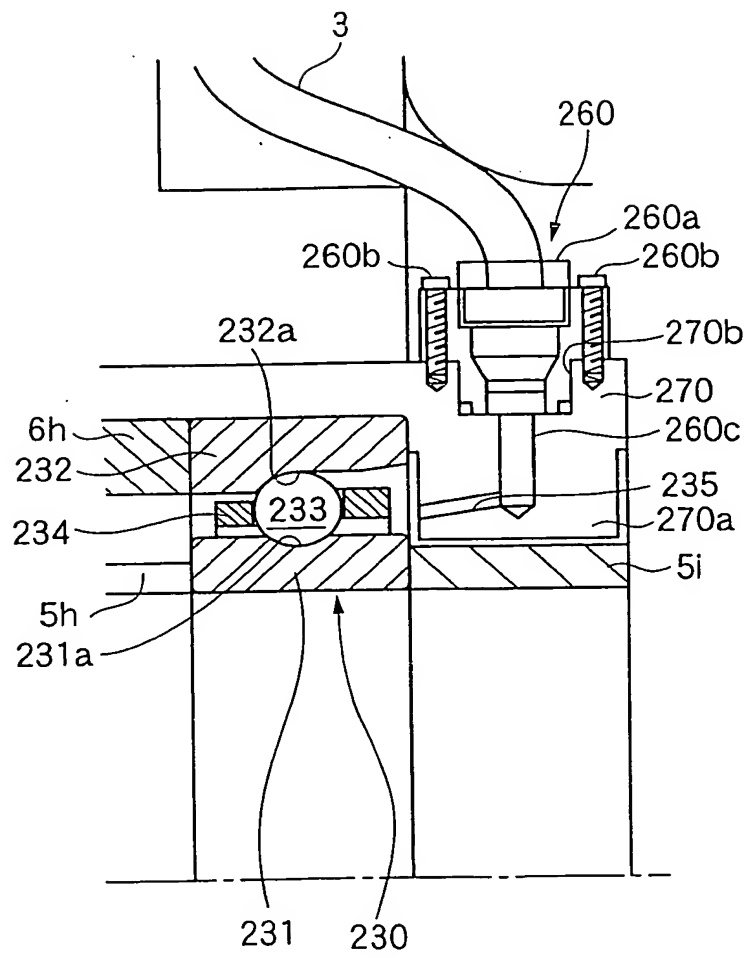


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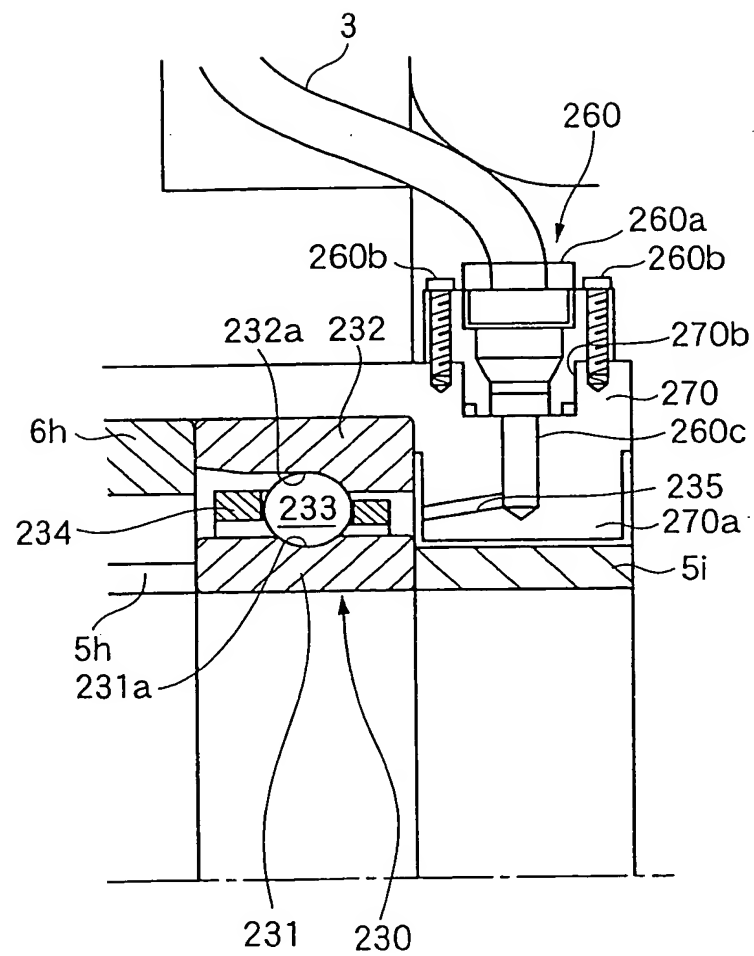


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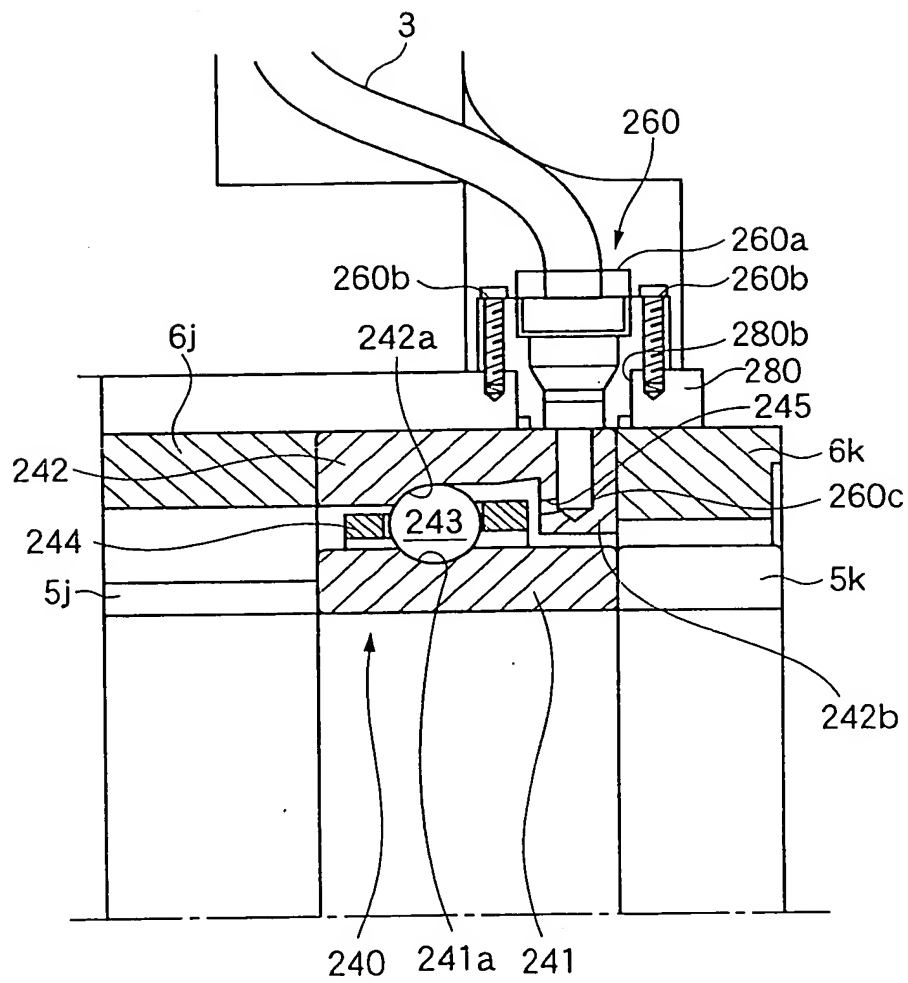


図 24

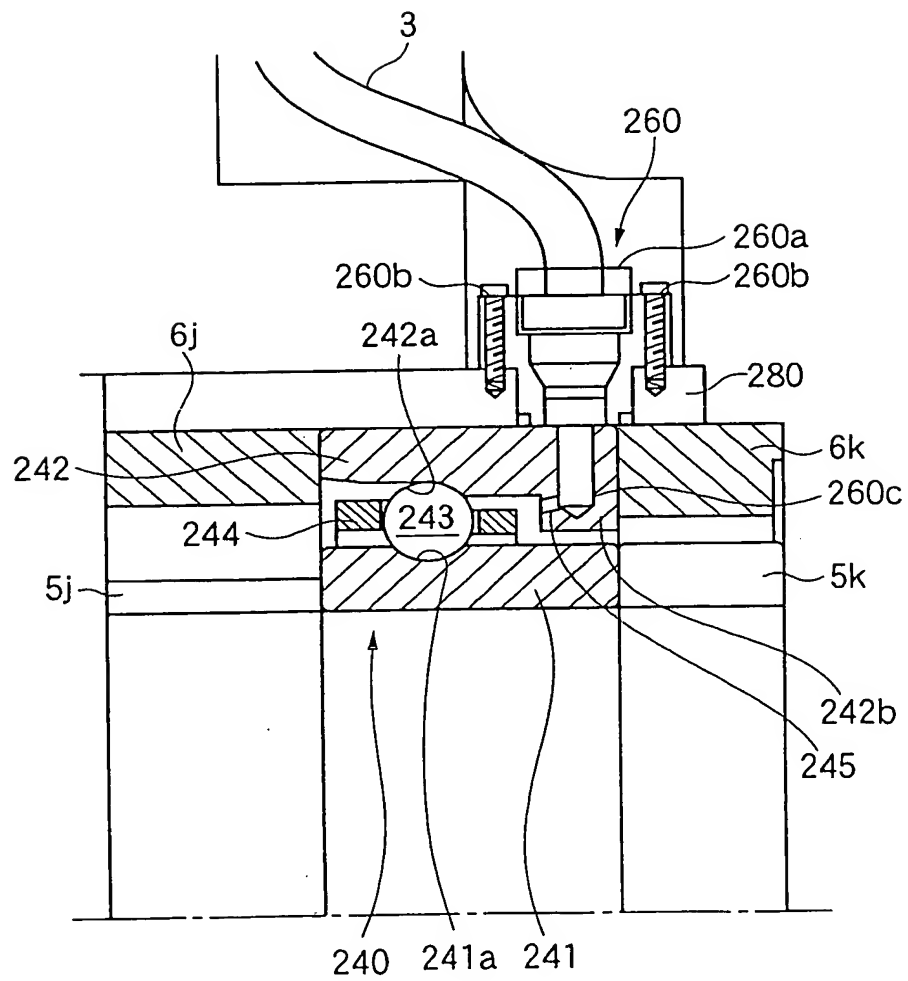


図 25

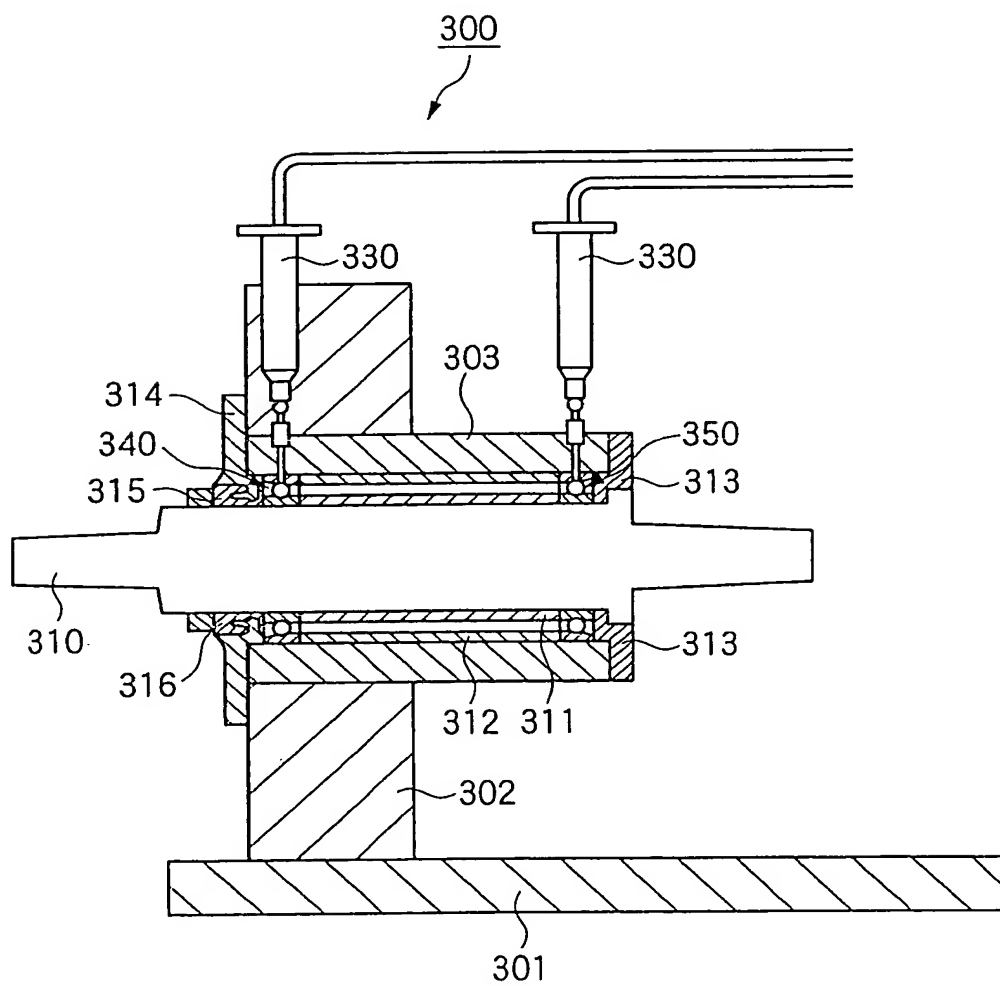


図 26

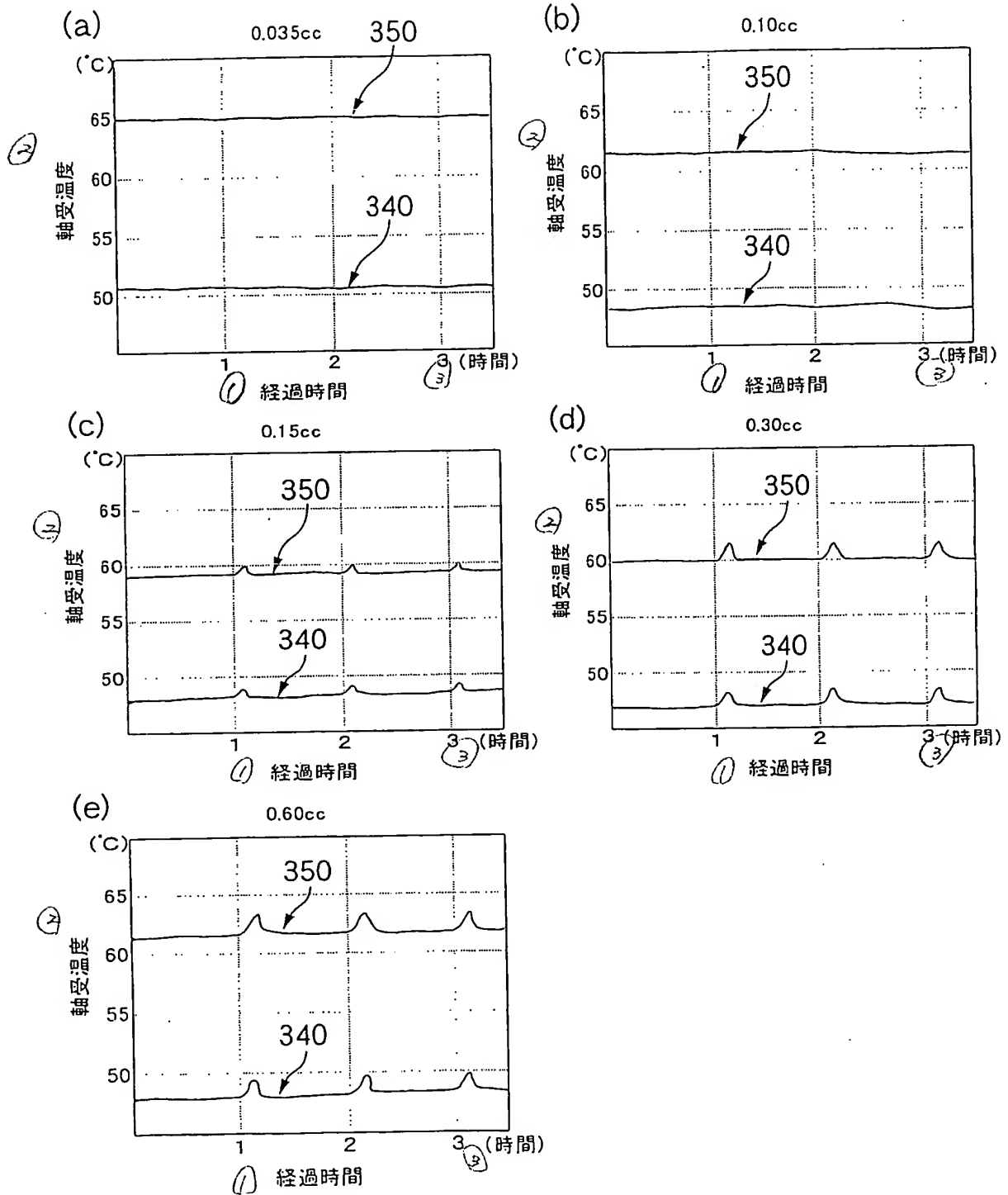


図 27

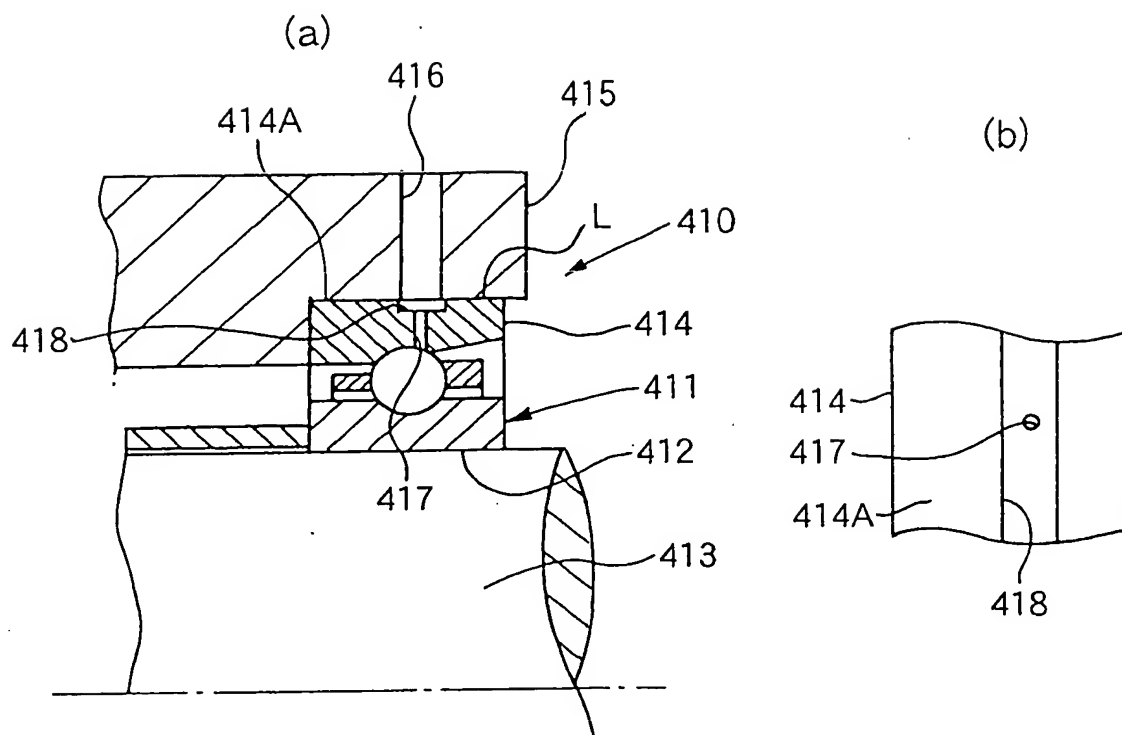


図 28

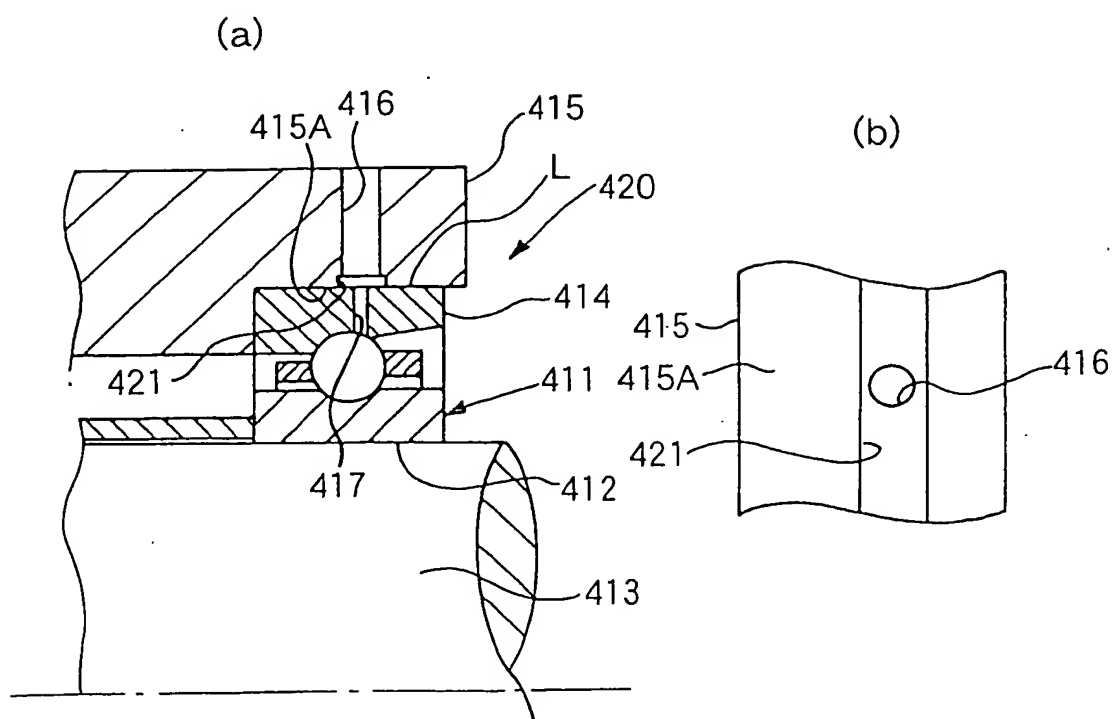


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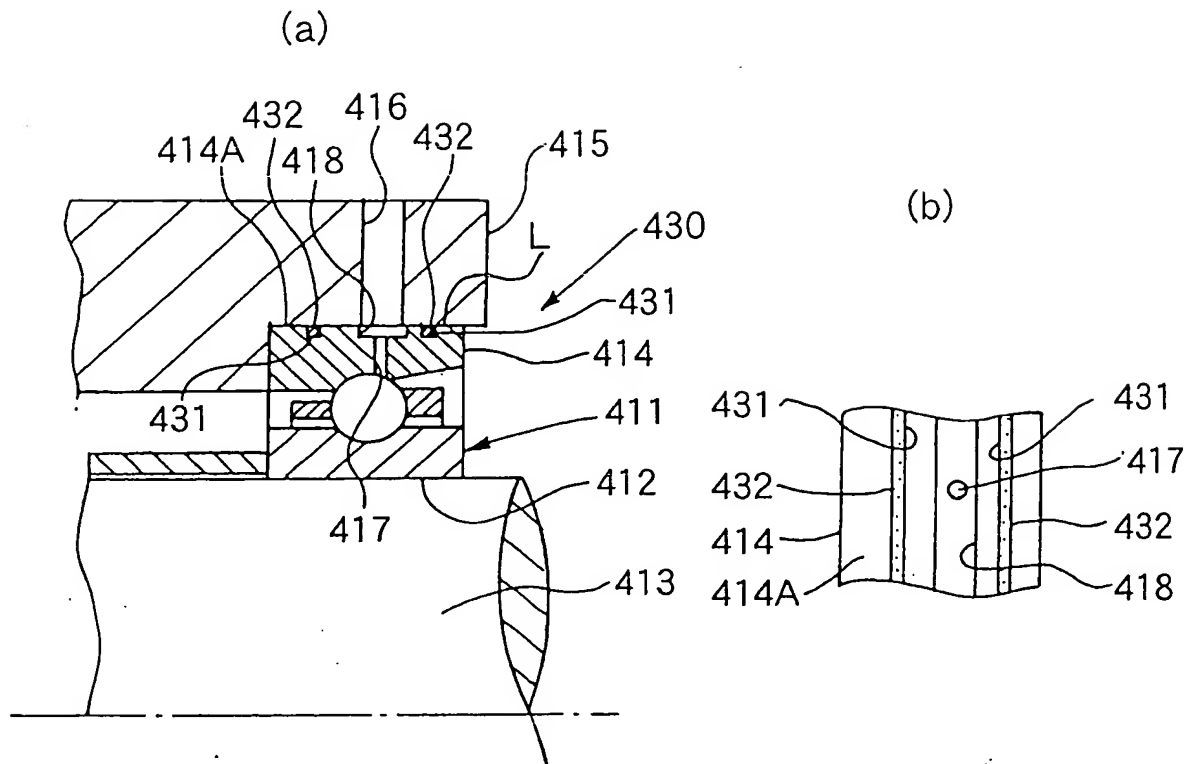


図 30

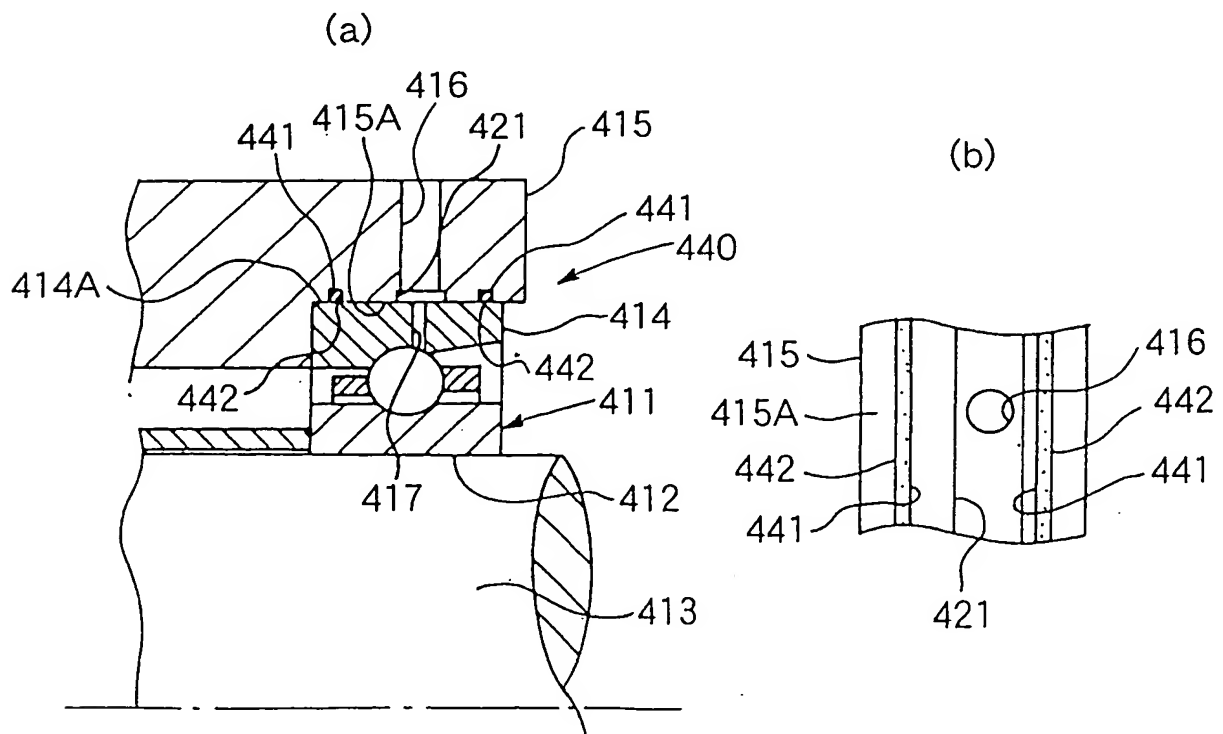


図 31

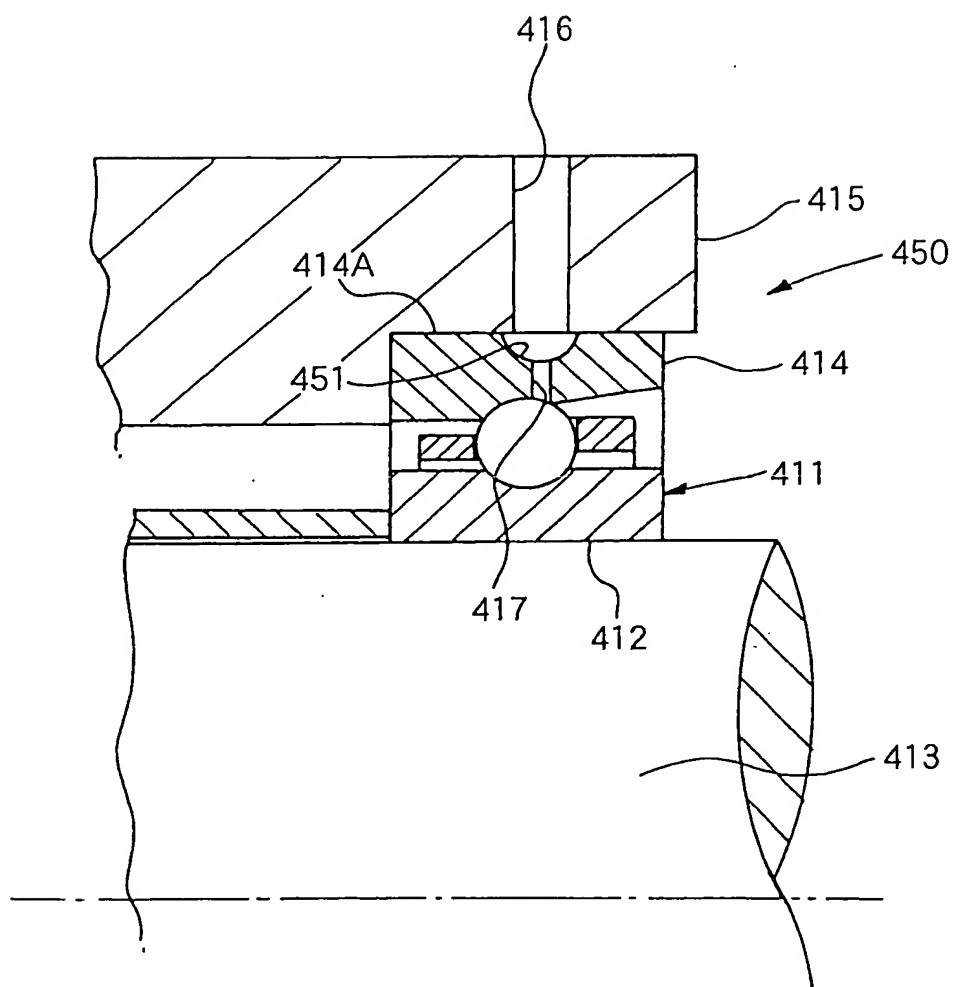


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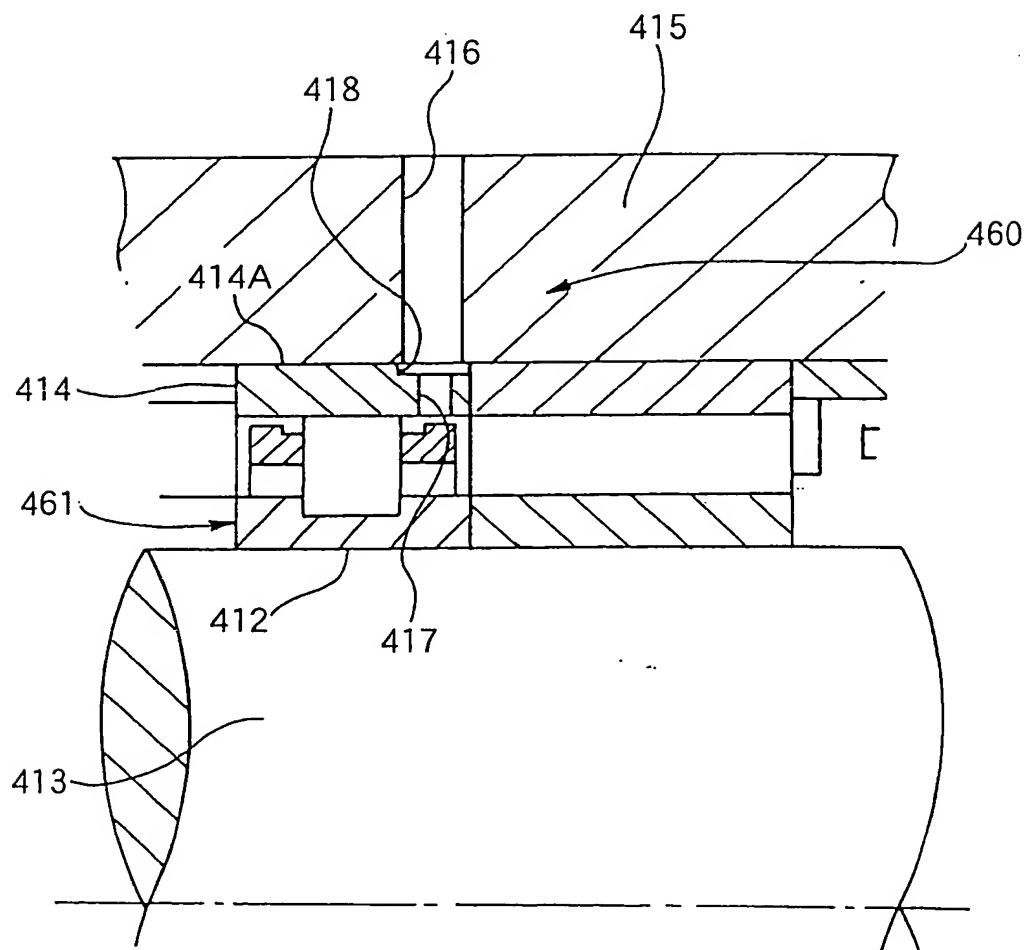


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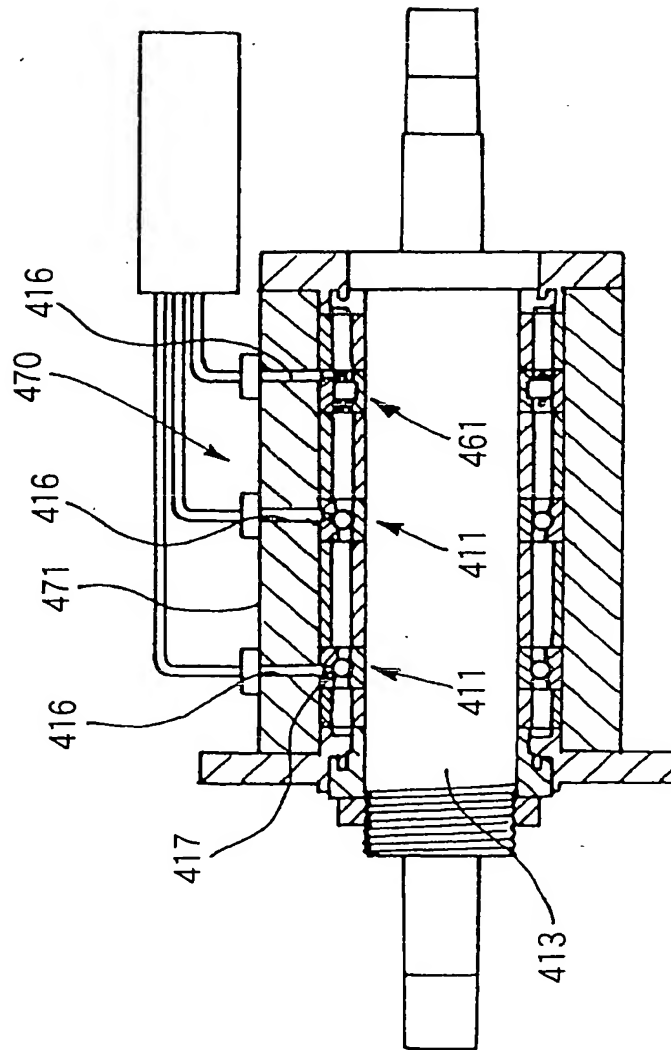




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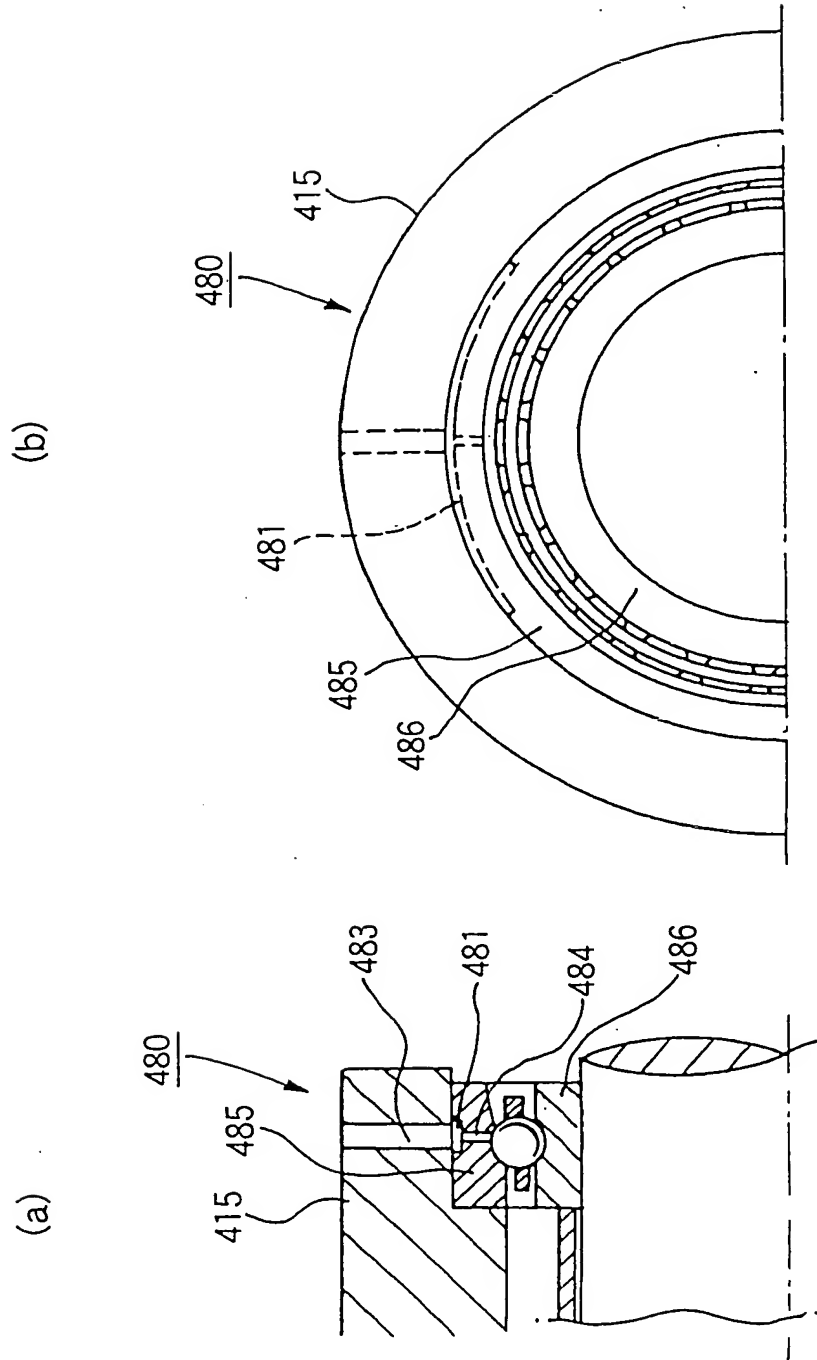


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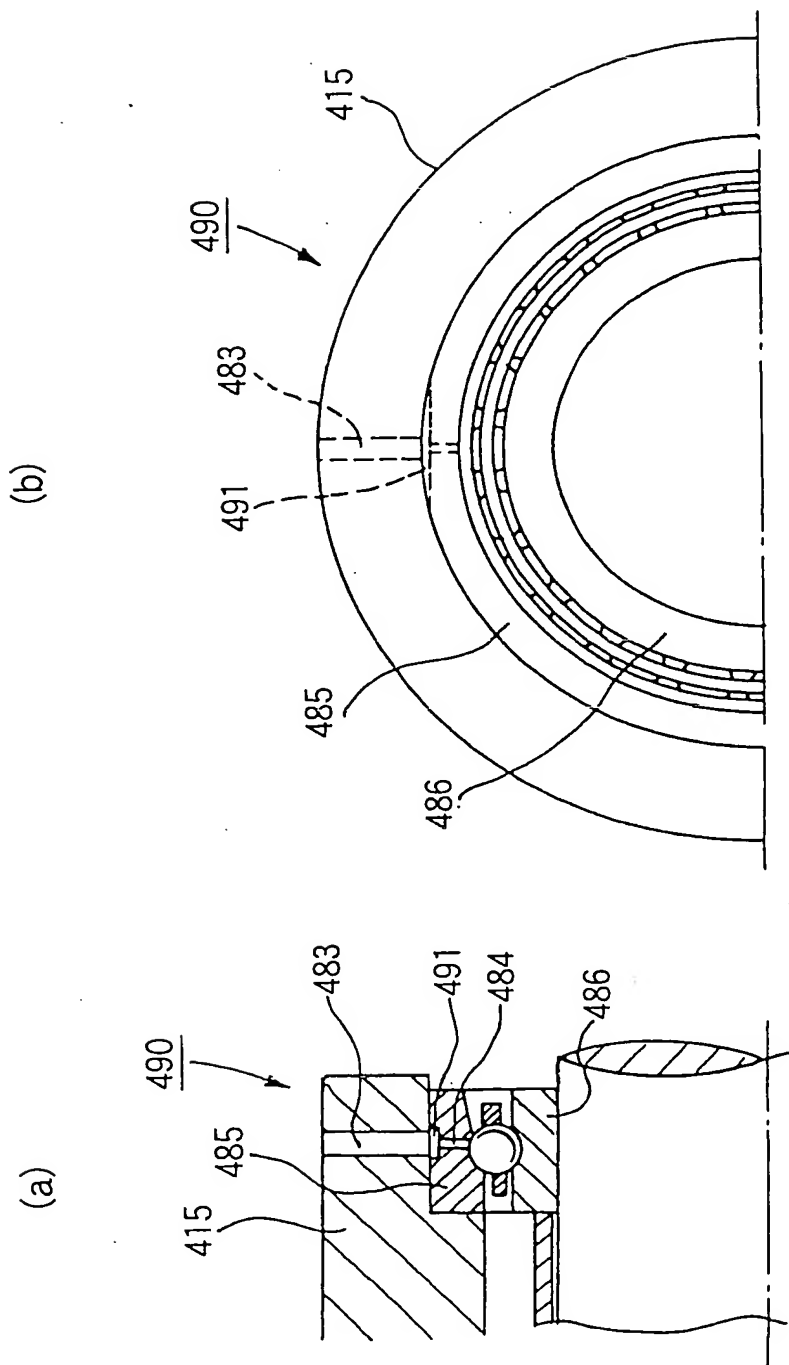
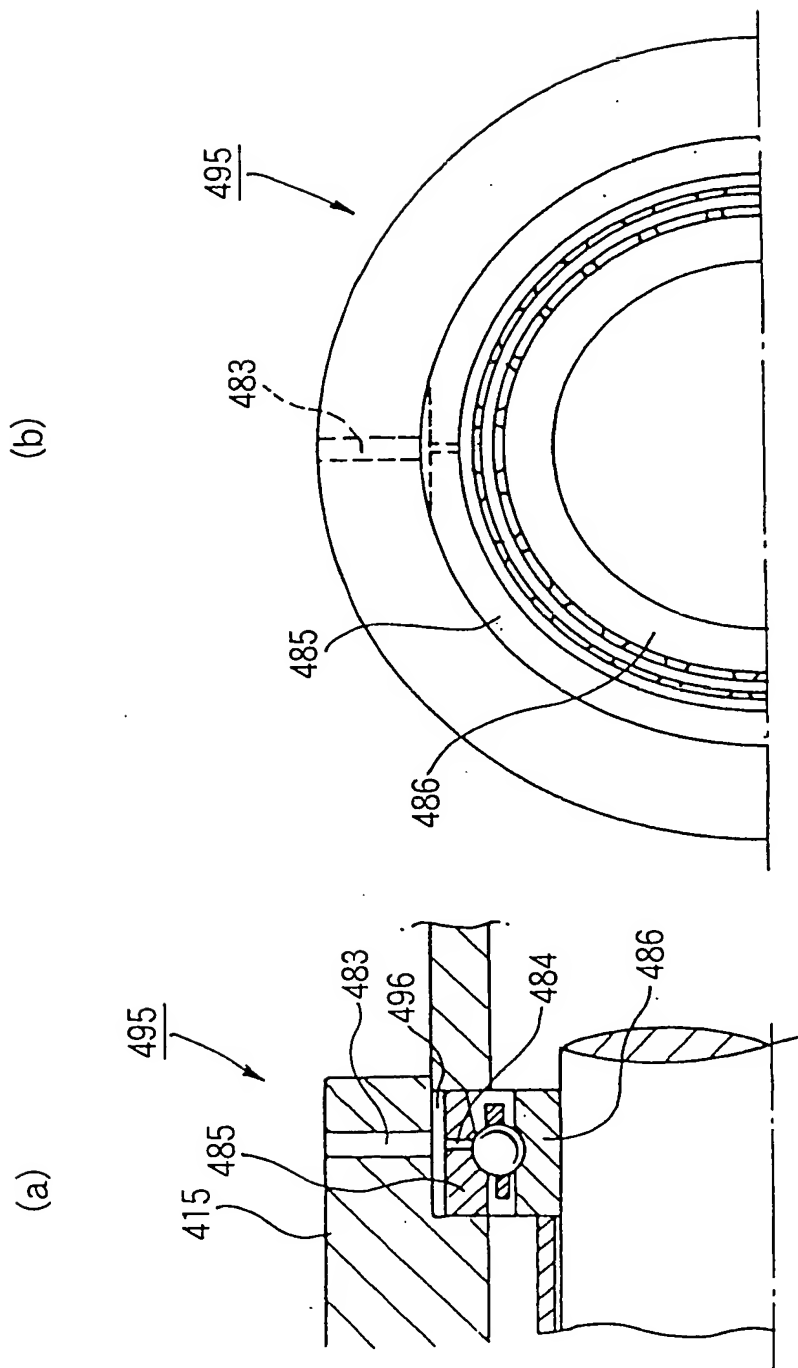


図 37



38

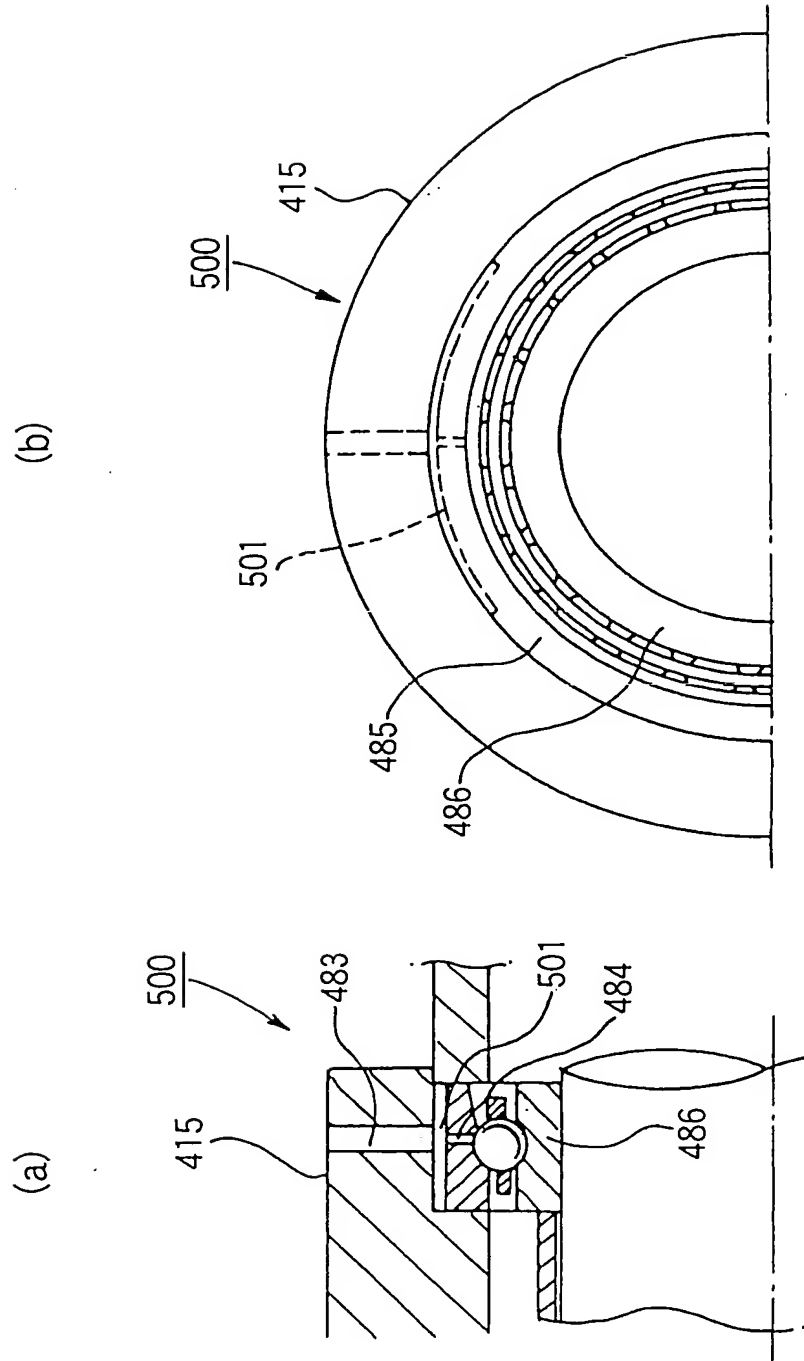


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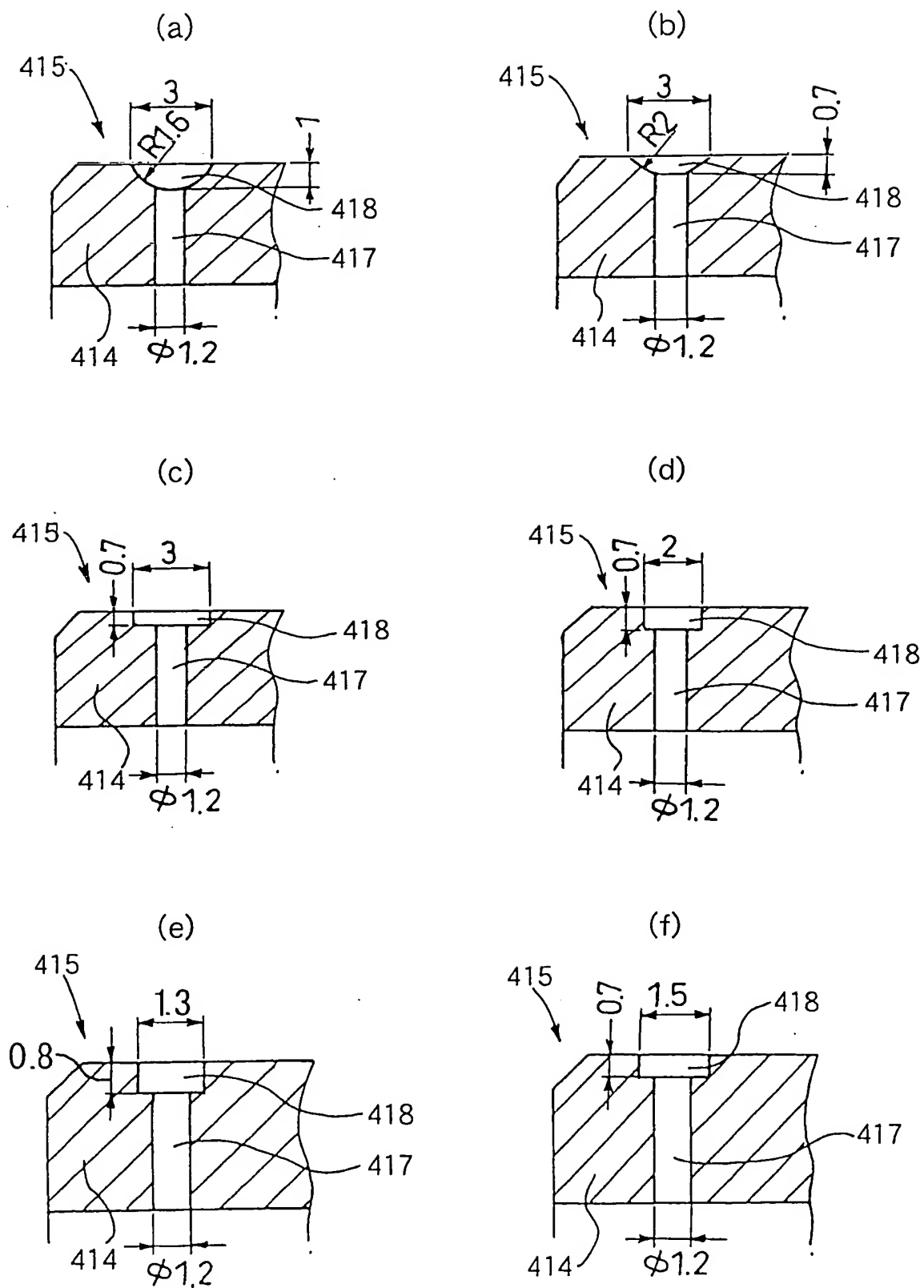


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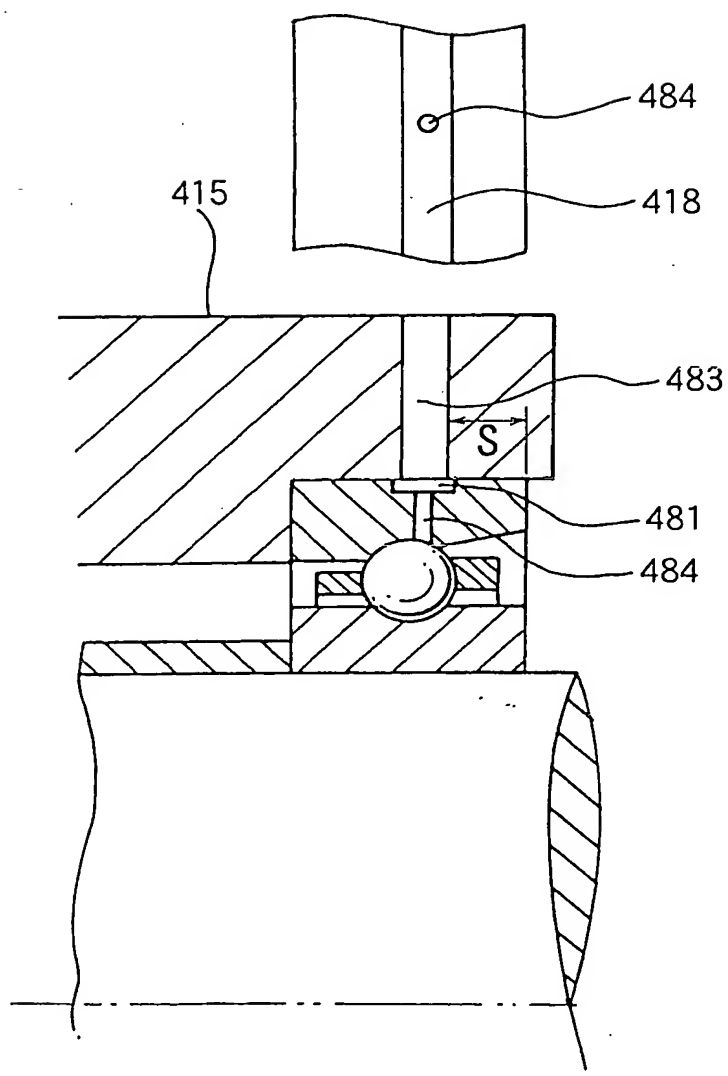


図 41

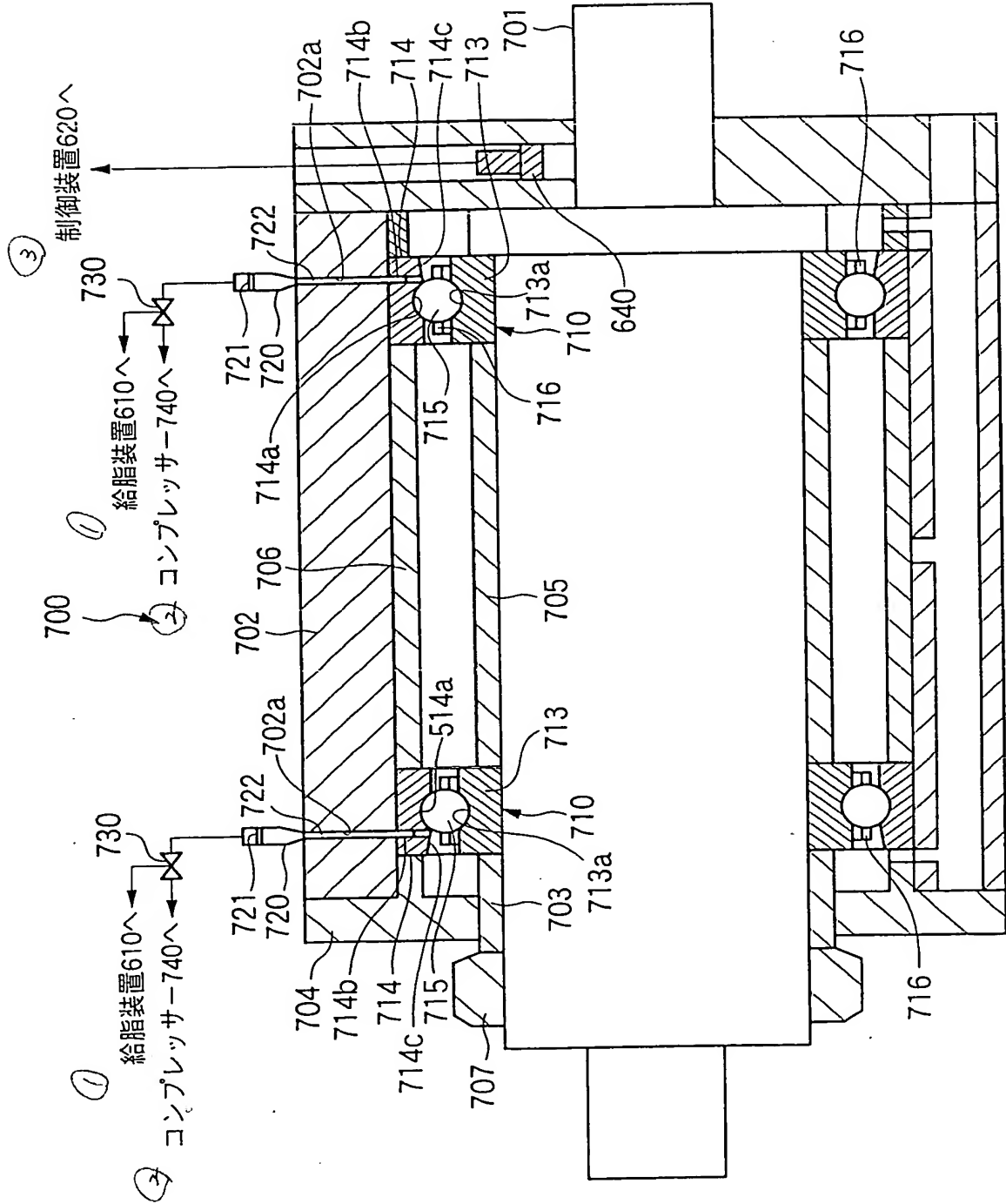


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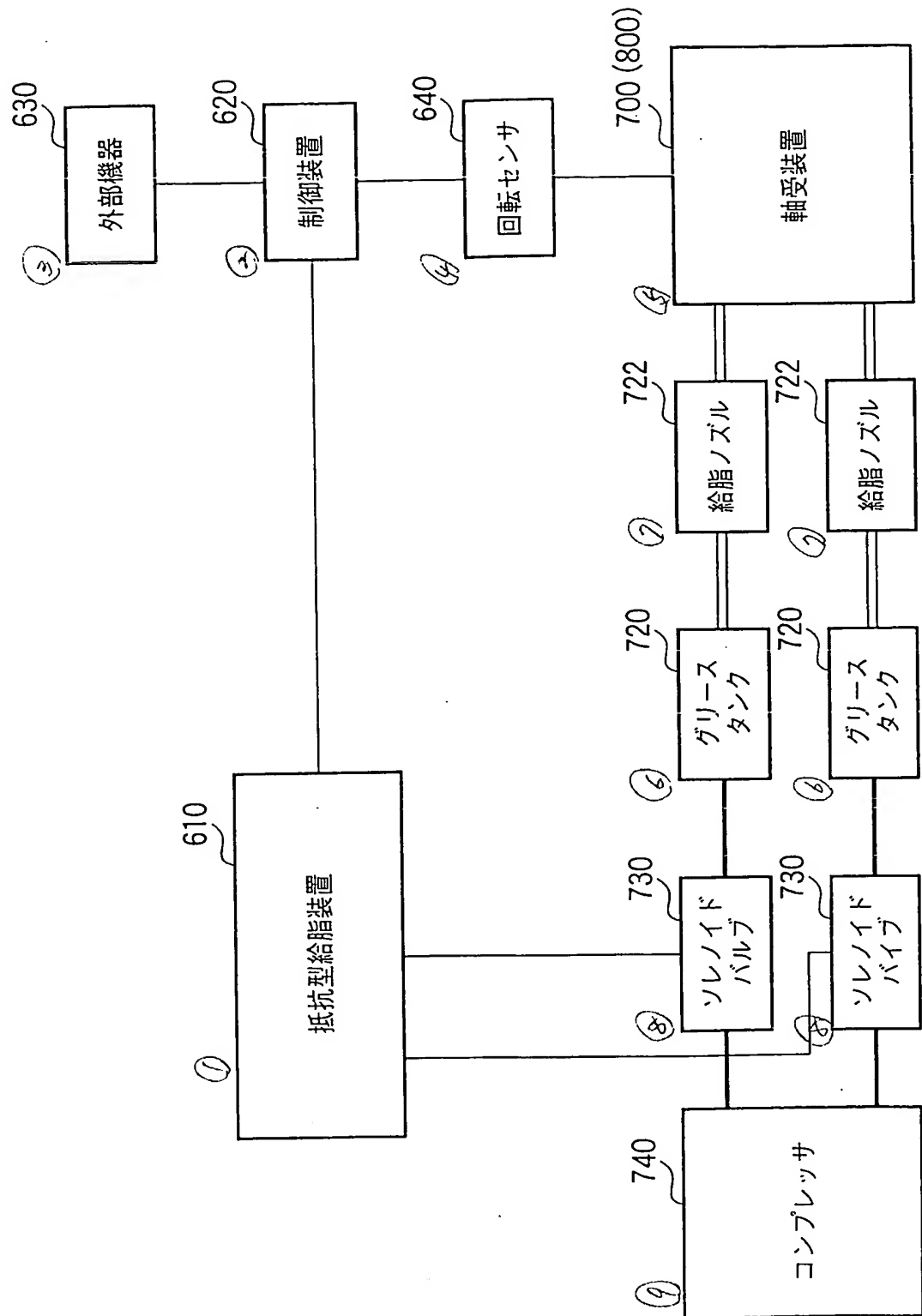


図 43

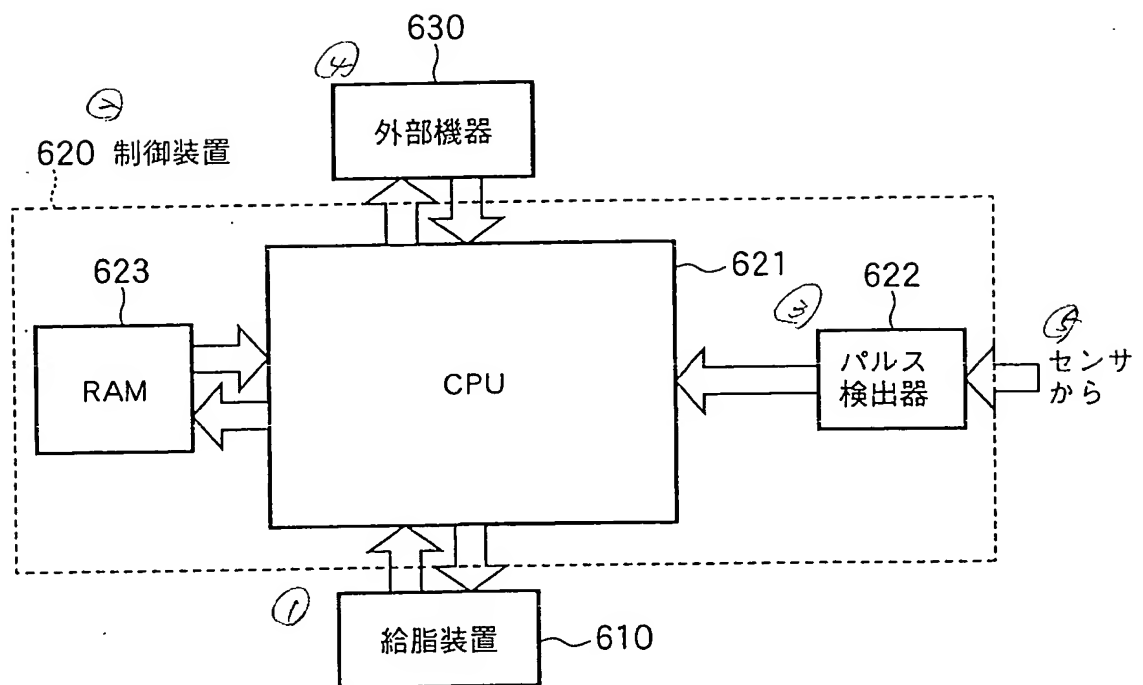


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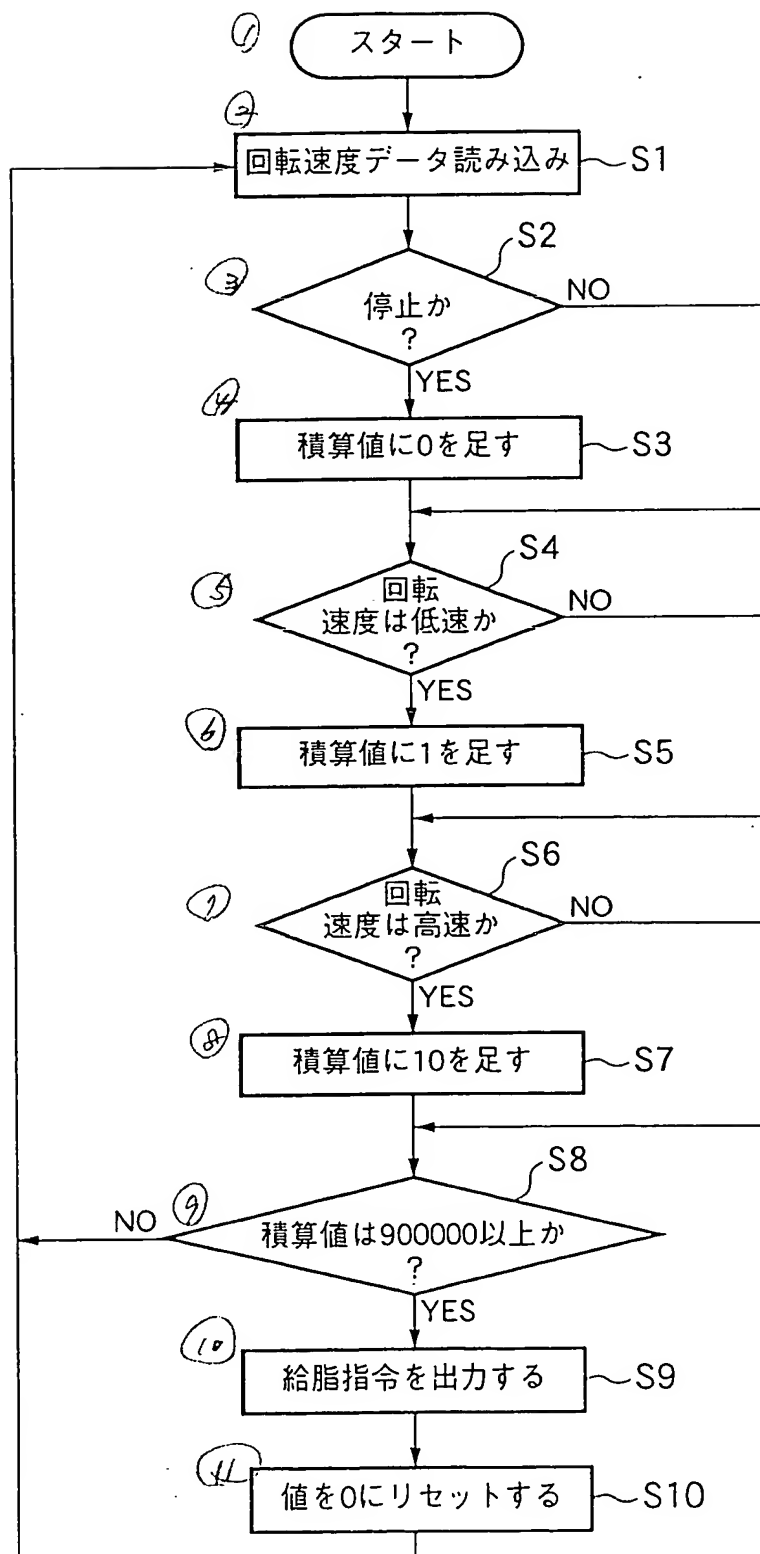


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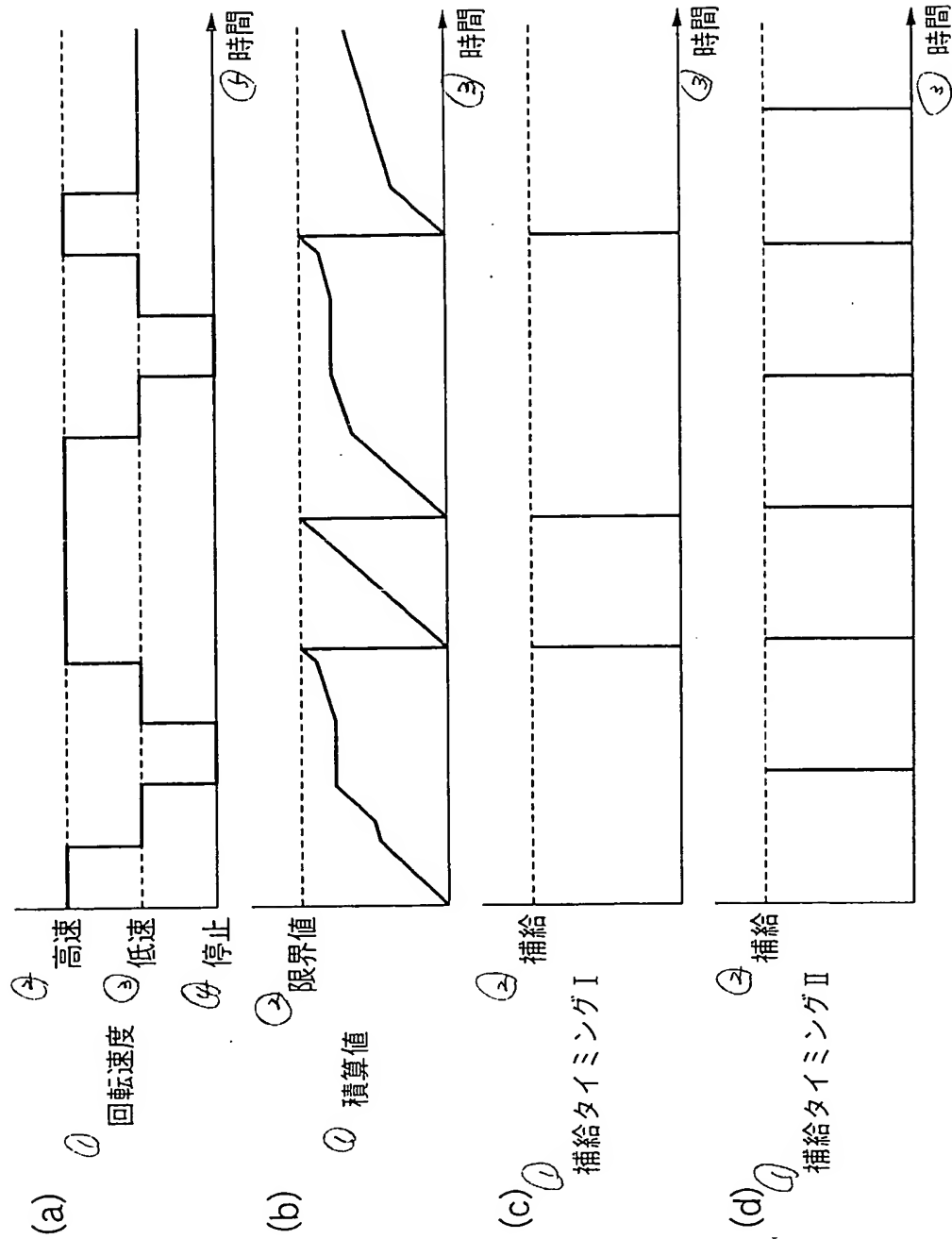


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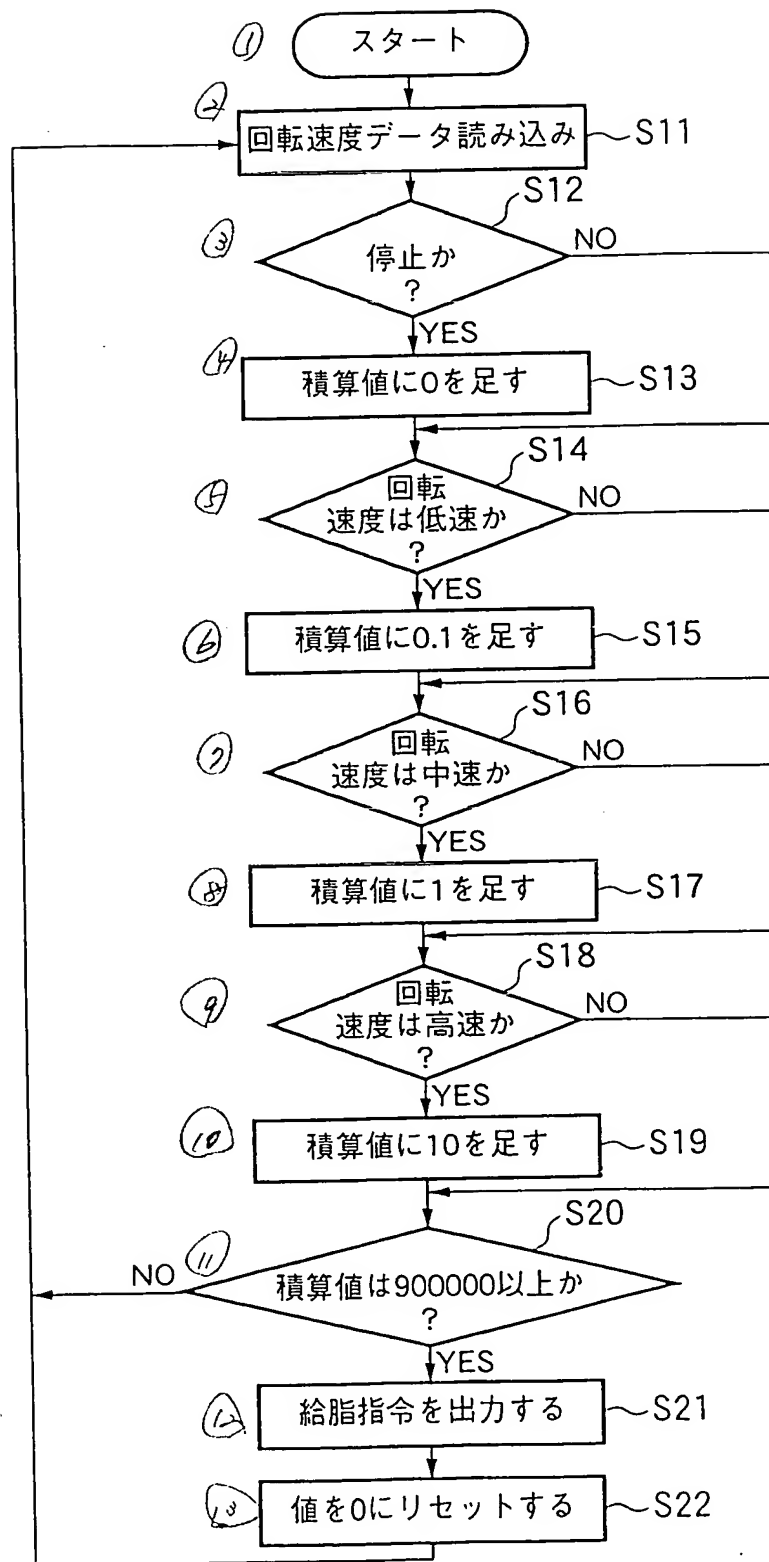


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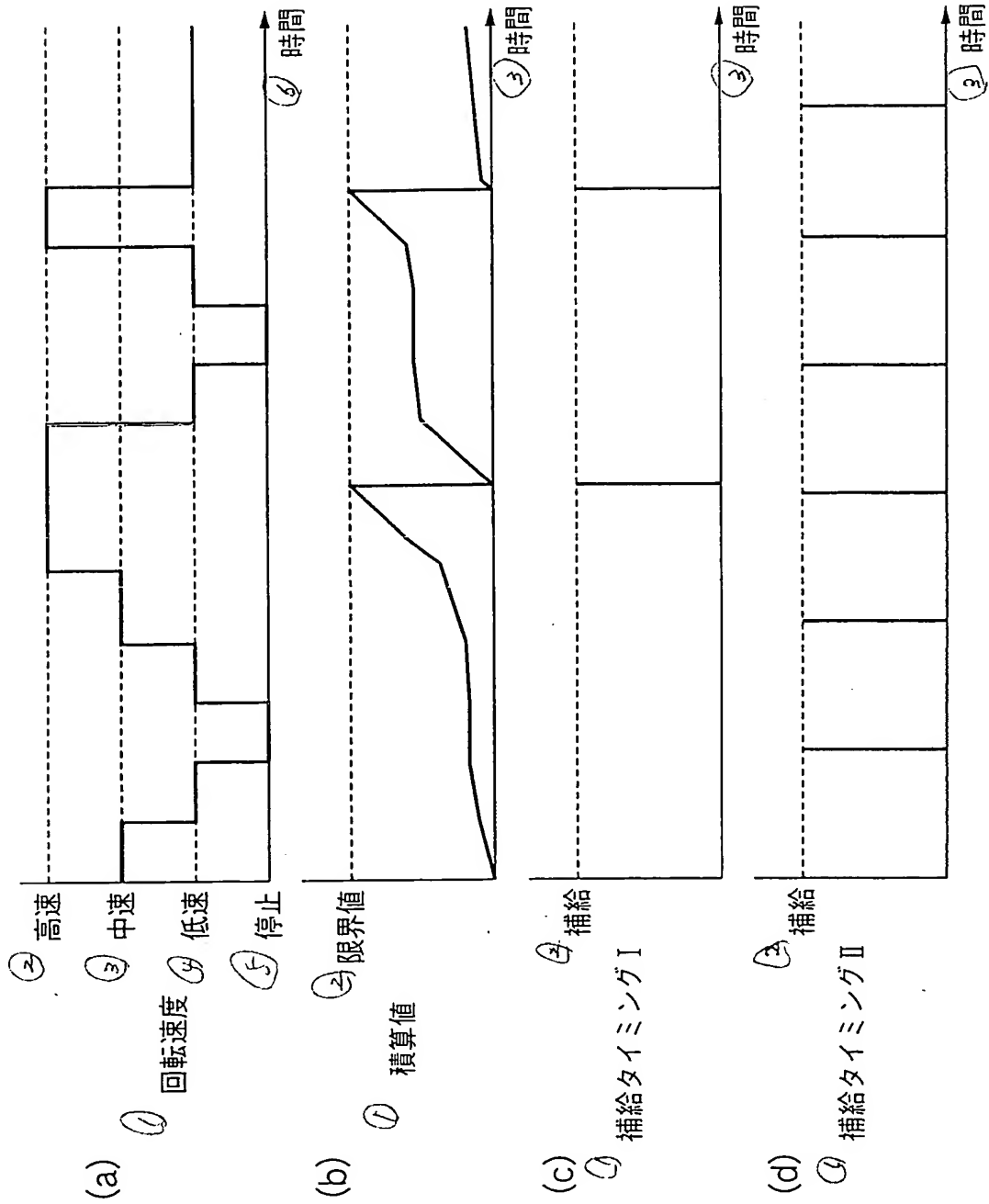


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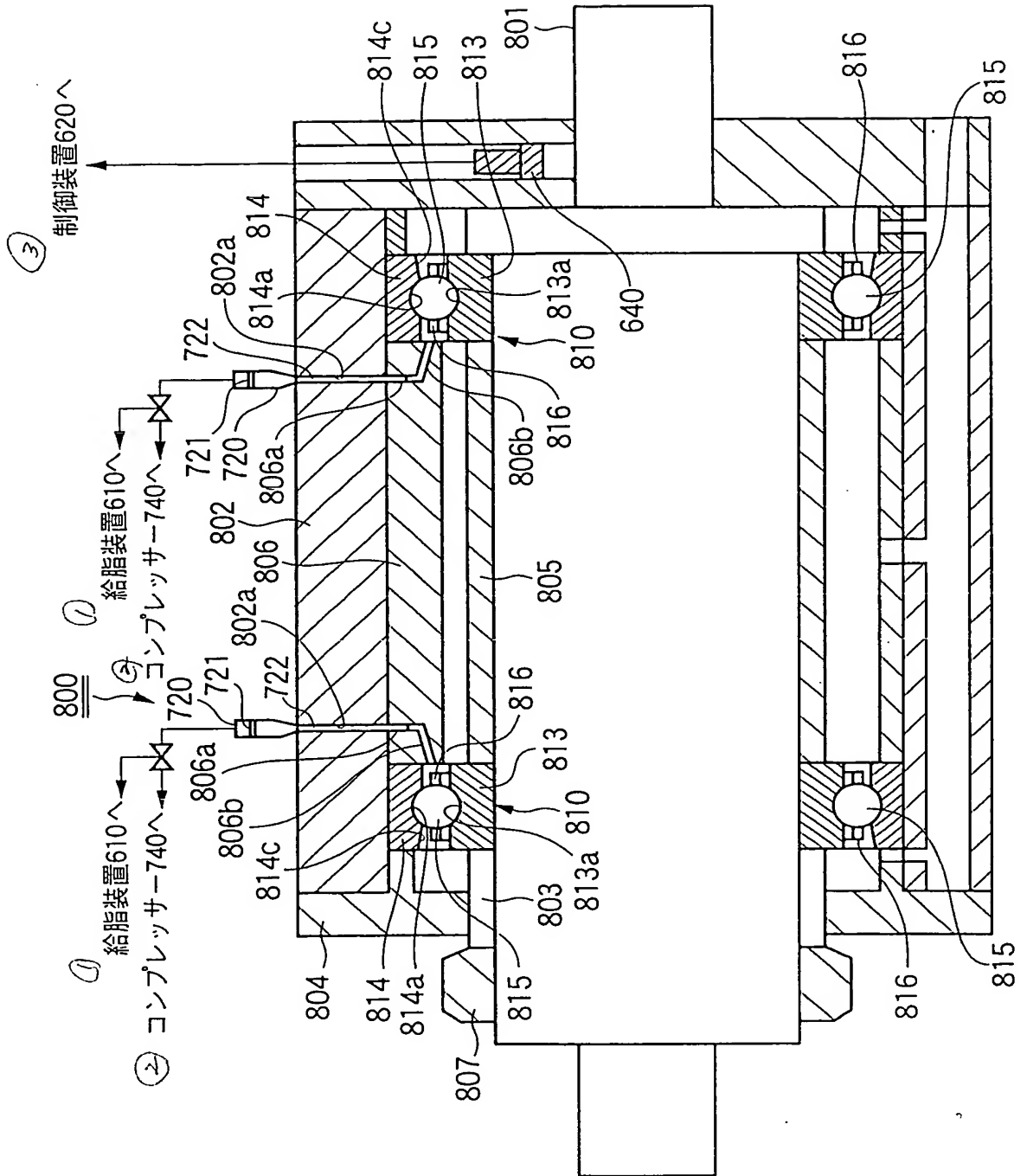


図 49

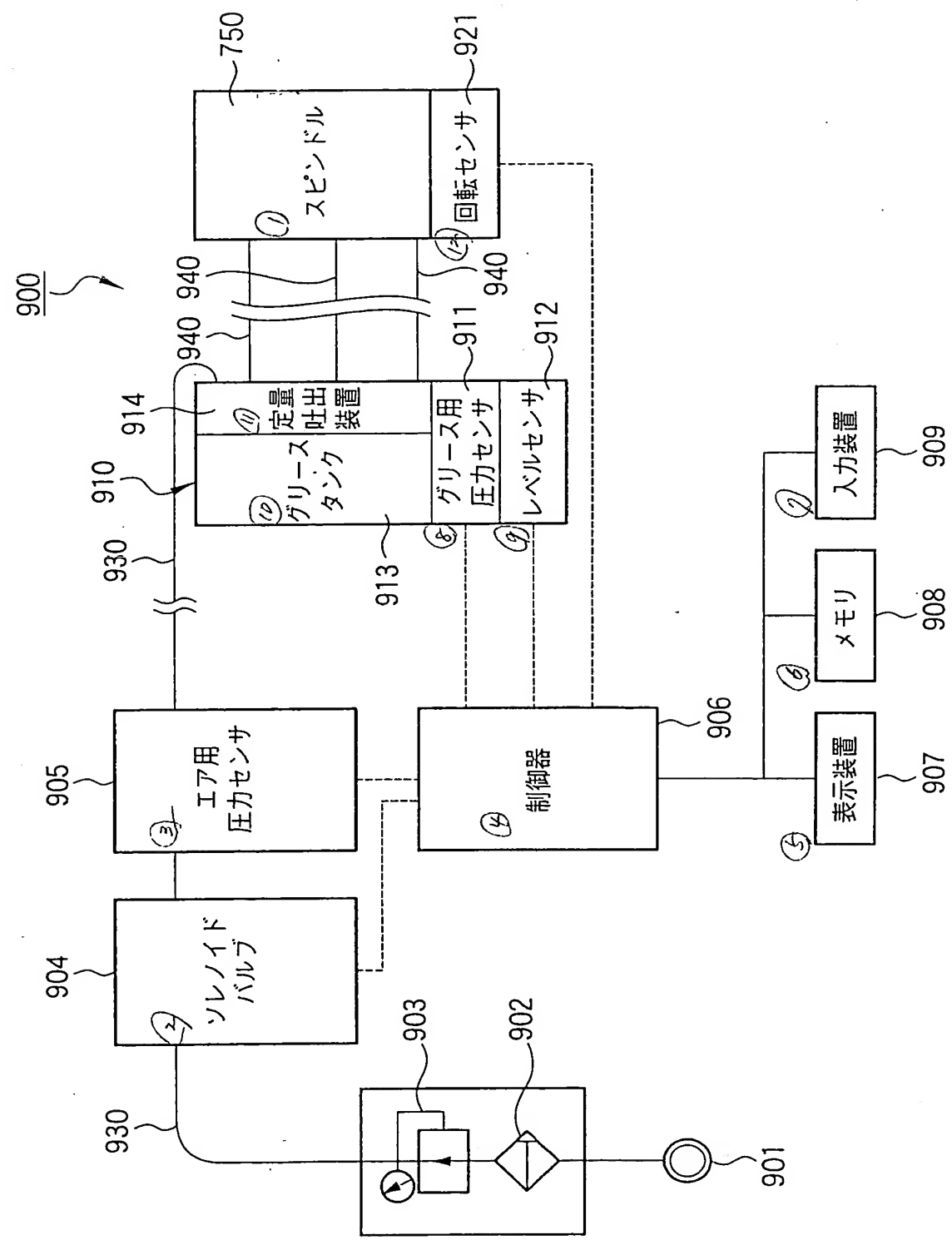


図 50

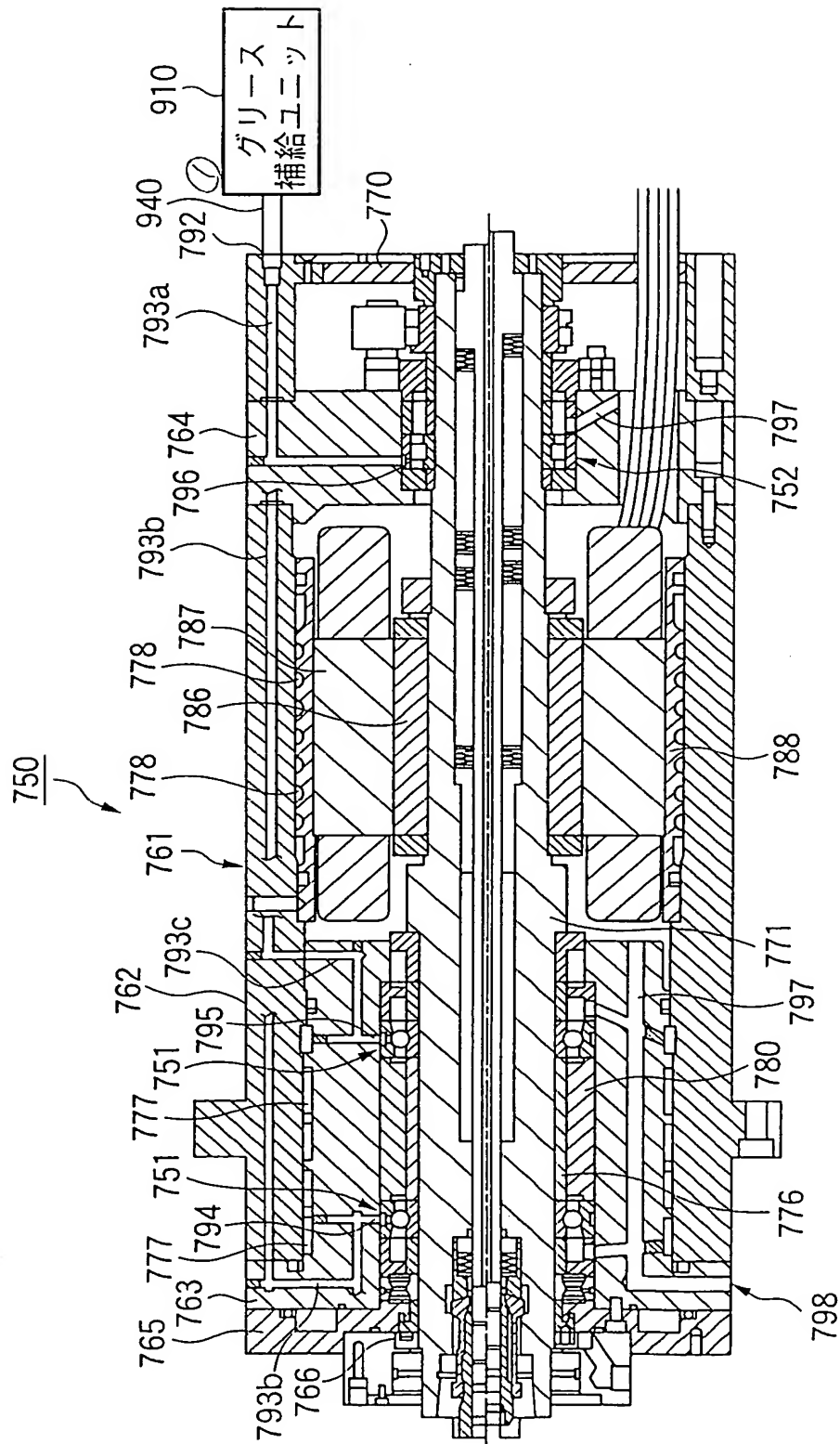


図 51

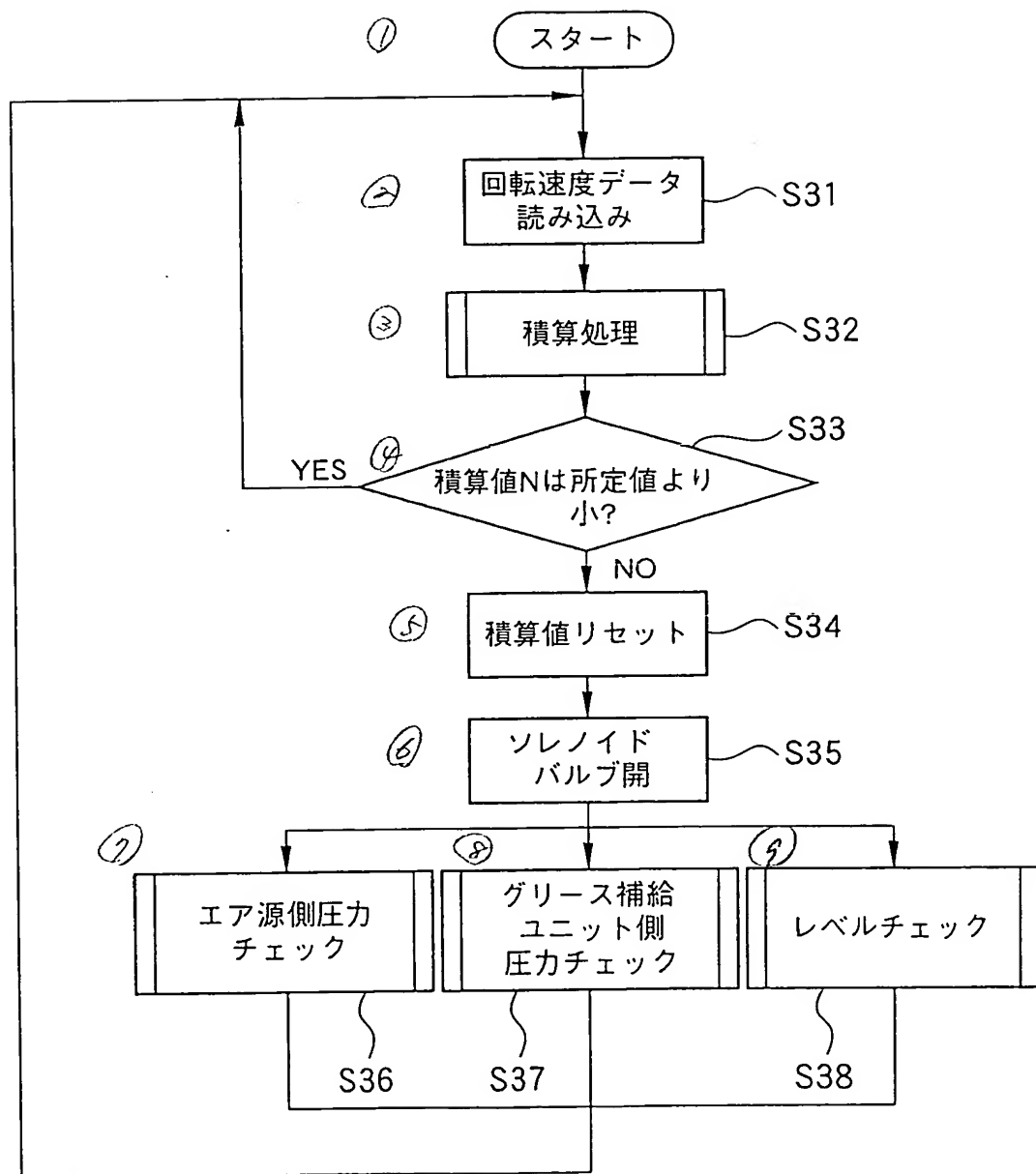


図 52

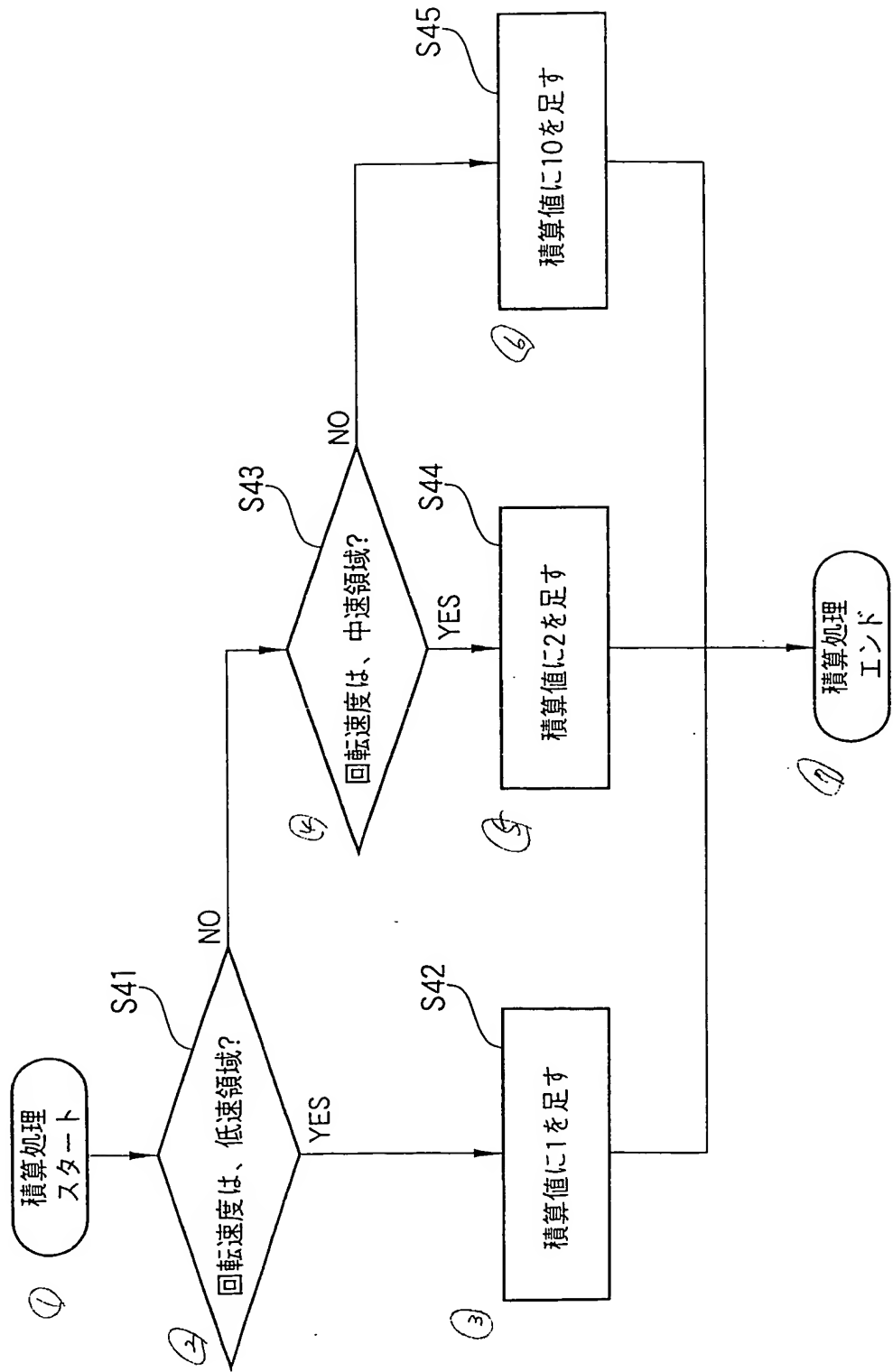


図 53

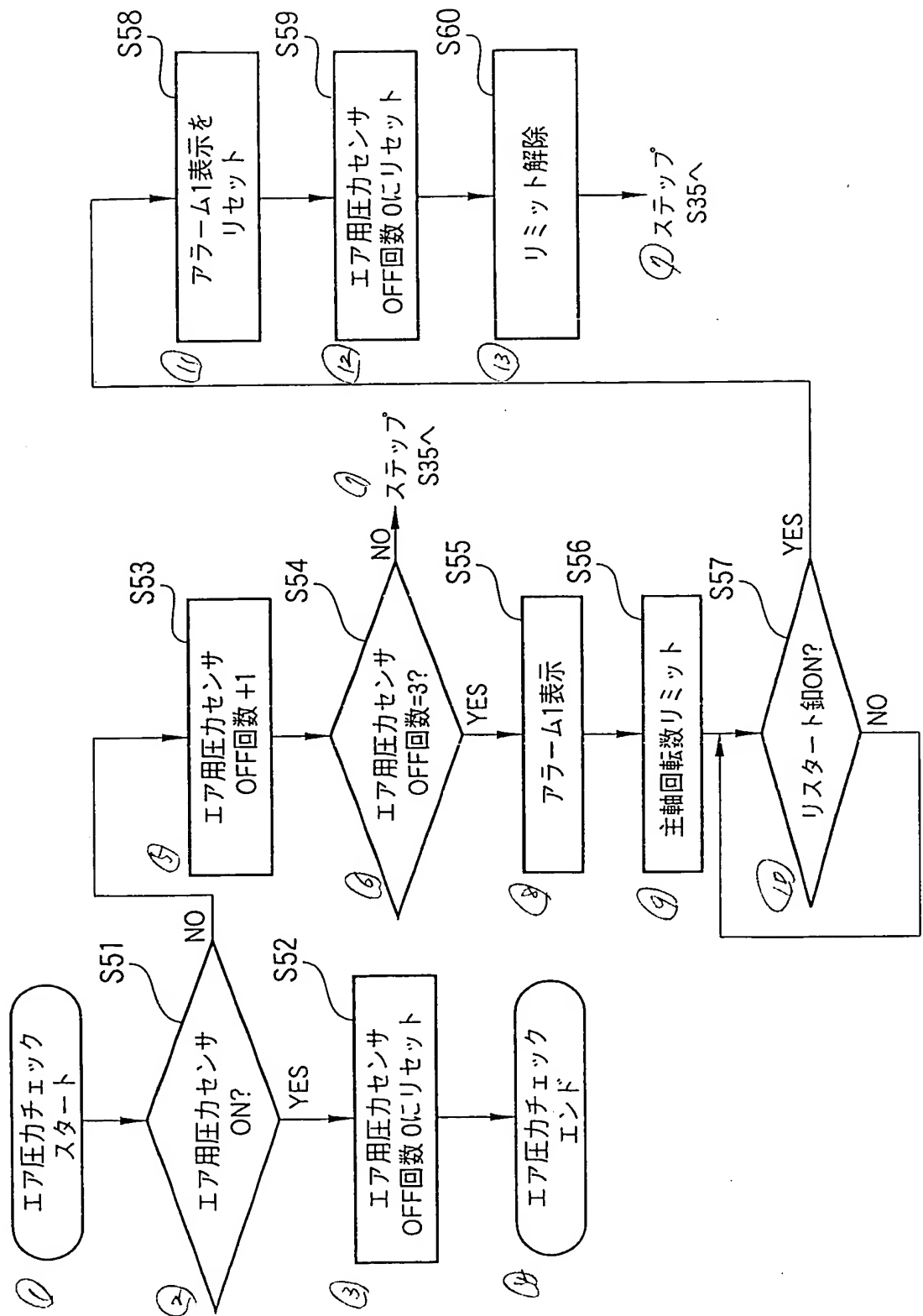


図 54

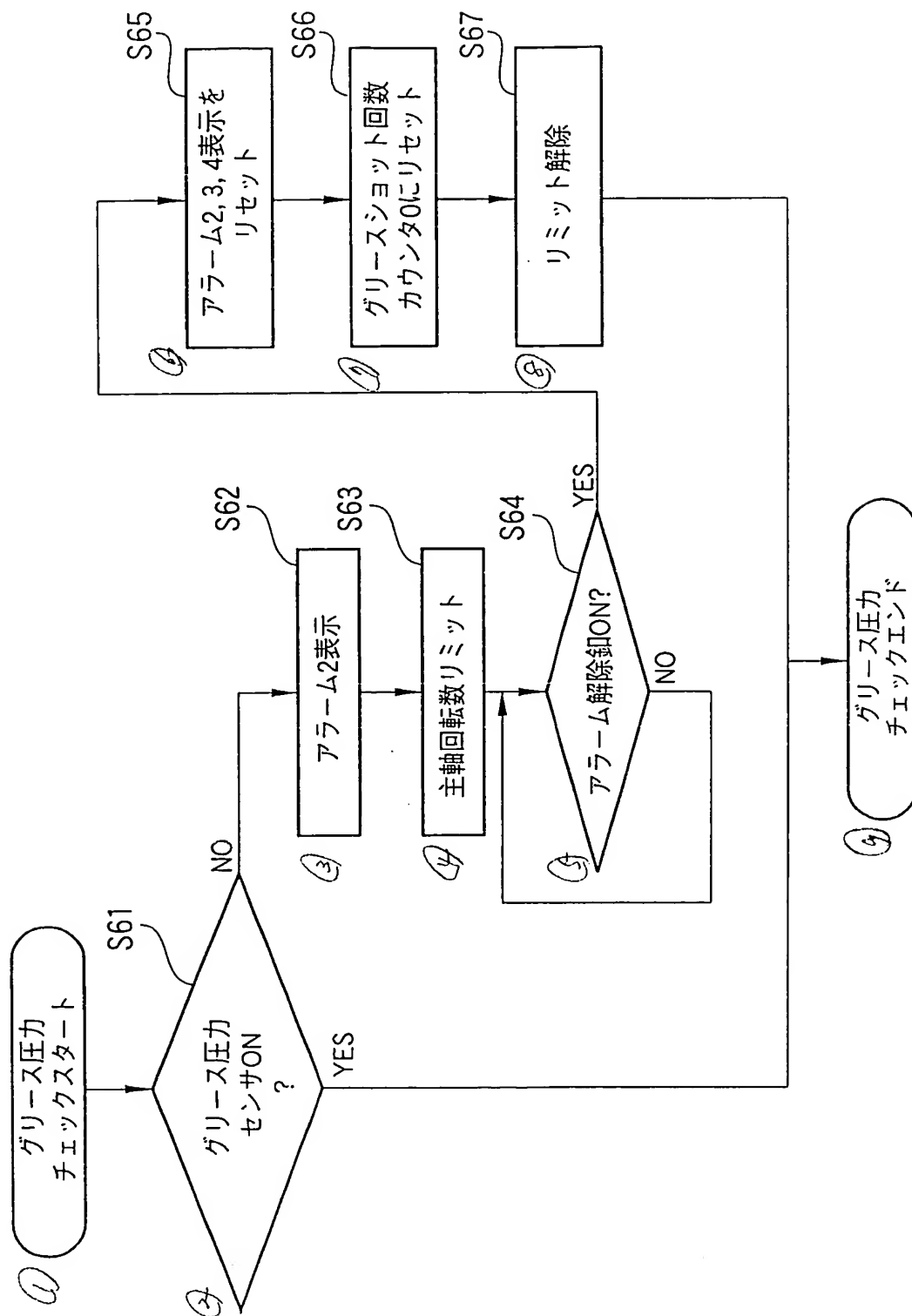


図 55

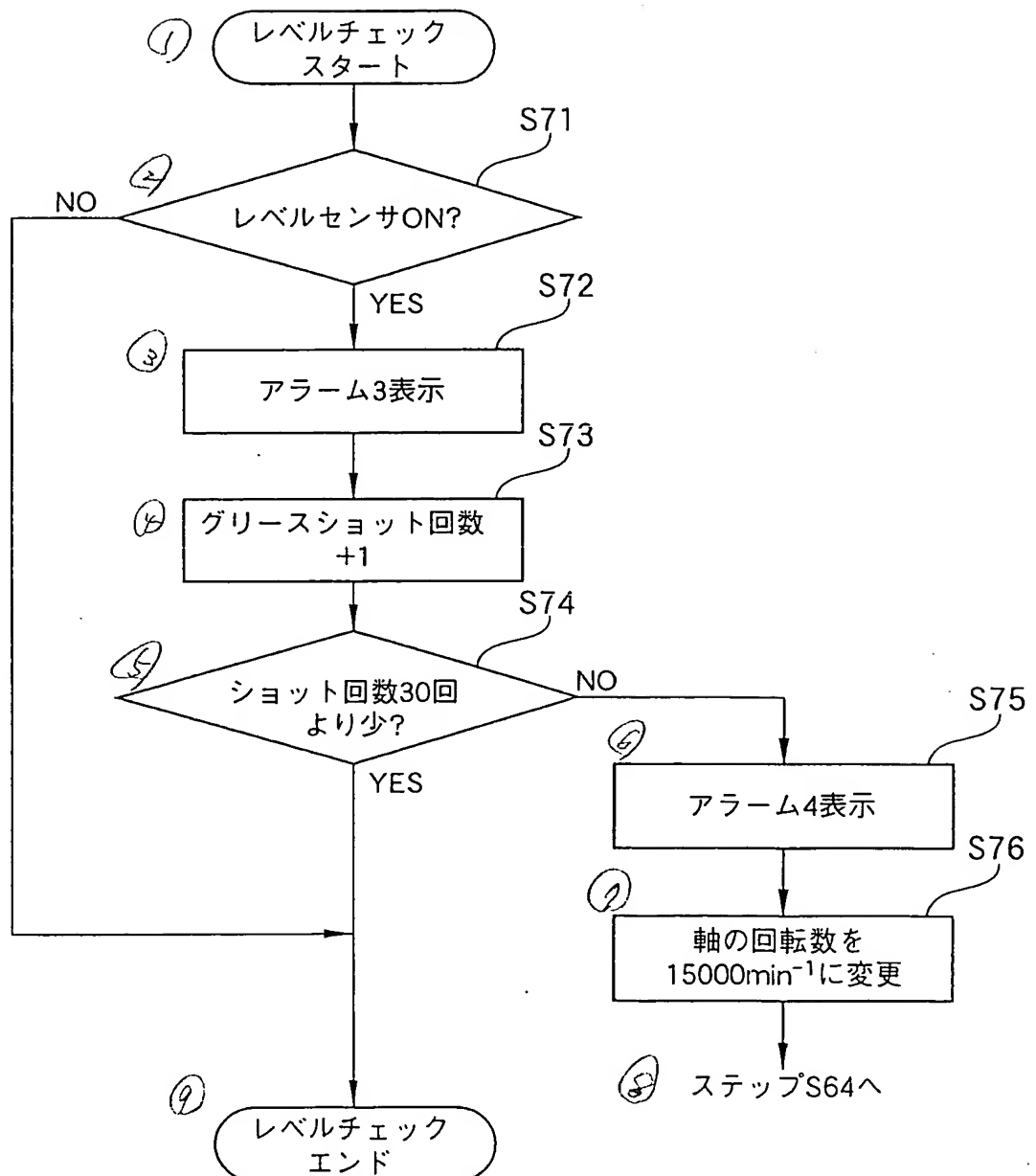


图 56

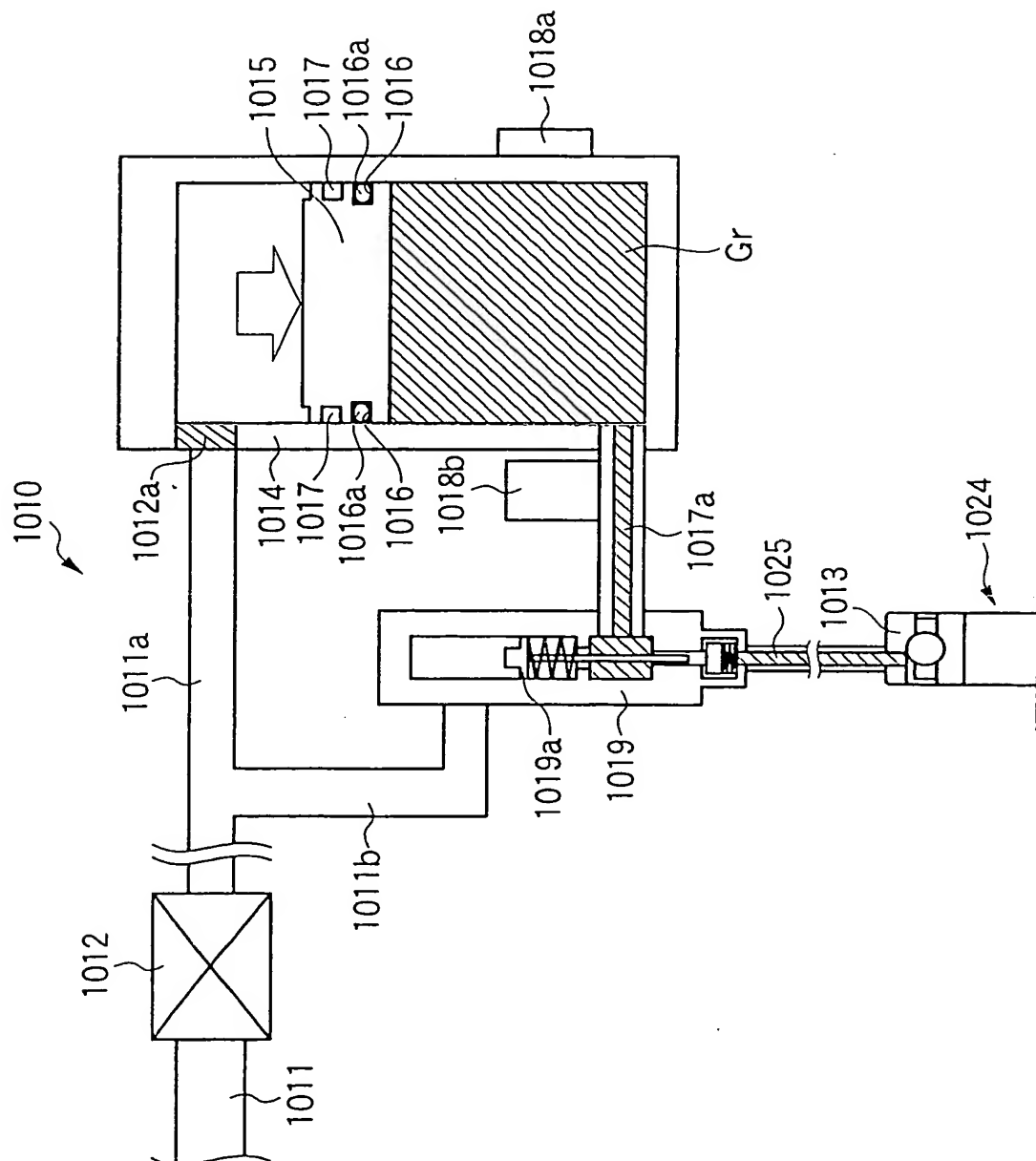


図 57

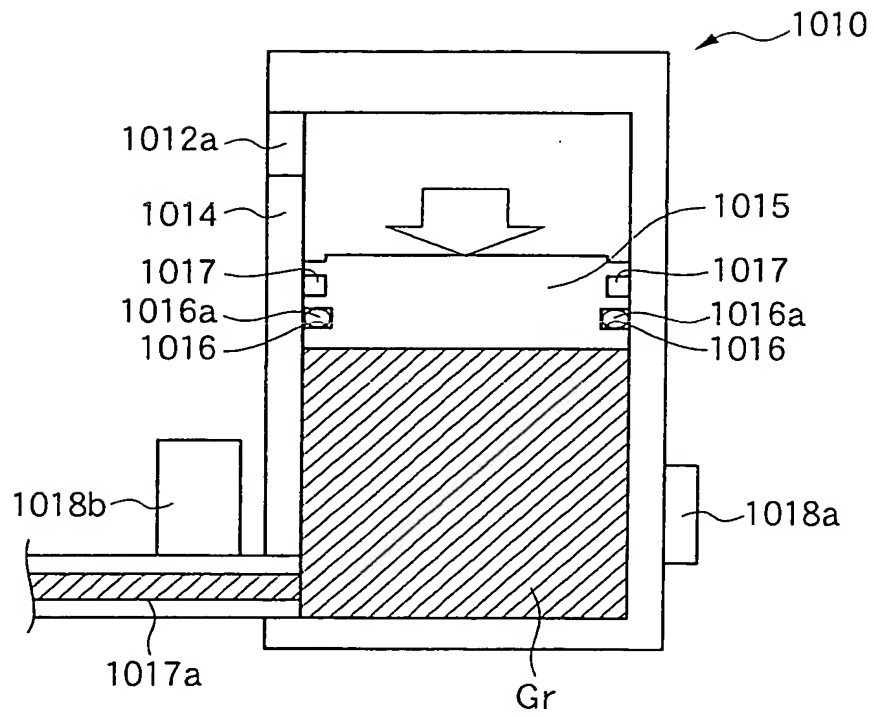


図 59

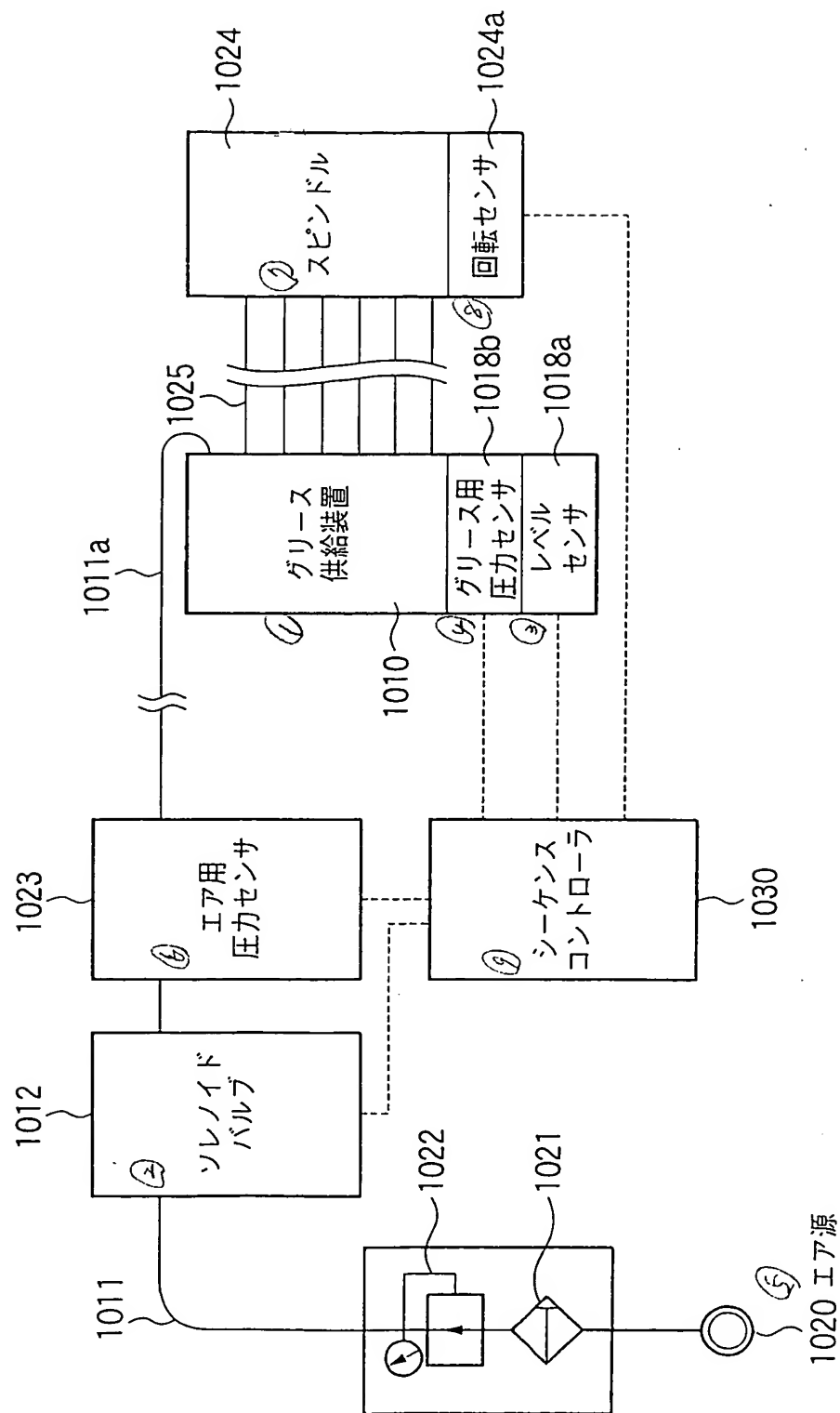


図 60

①

②

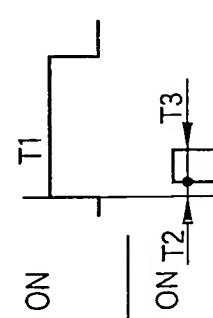
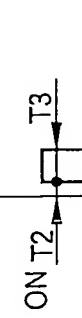
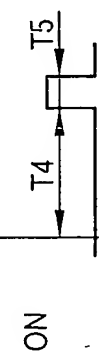
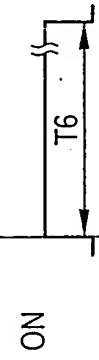
名称	作動タイミングと監視時間	③ 動作		④ 内容
⑤ ソレノイドバルブ	ON 	—	—	—
⑥ エア用圧力センサ	ON 	OFF	⑨ エア圧力低下	
⑦ グリース用圧力センサ	ON 	OFF	⑩ グリースタンク 圧力低下	
⑧ レベルセンサ	ON 	ON	⑪ グリースタンク 残存量不足	

図 61

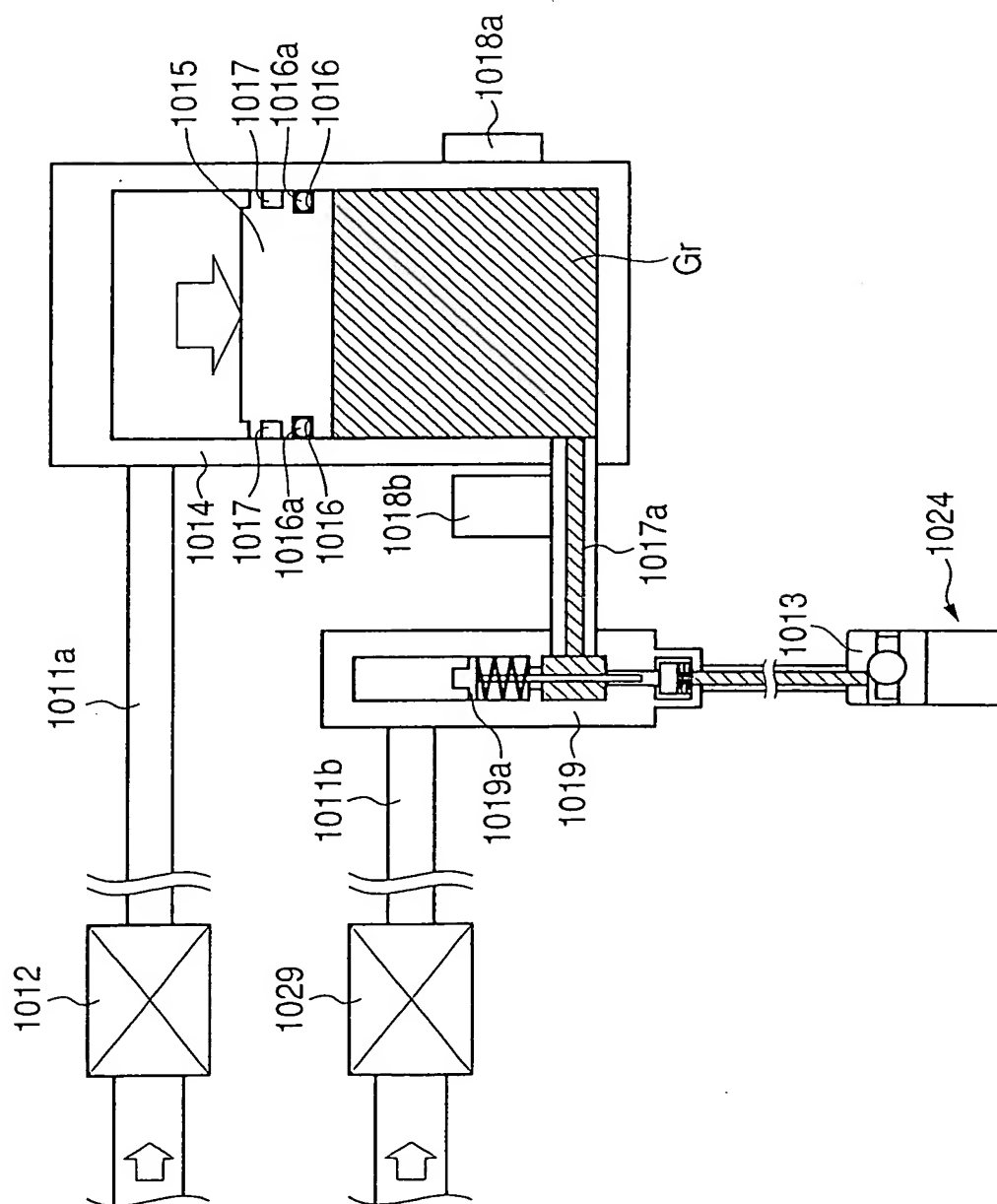


図 62

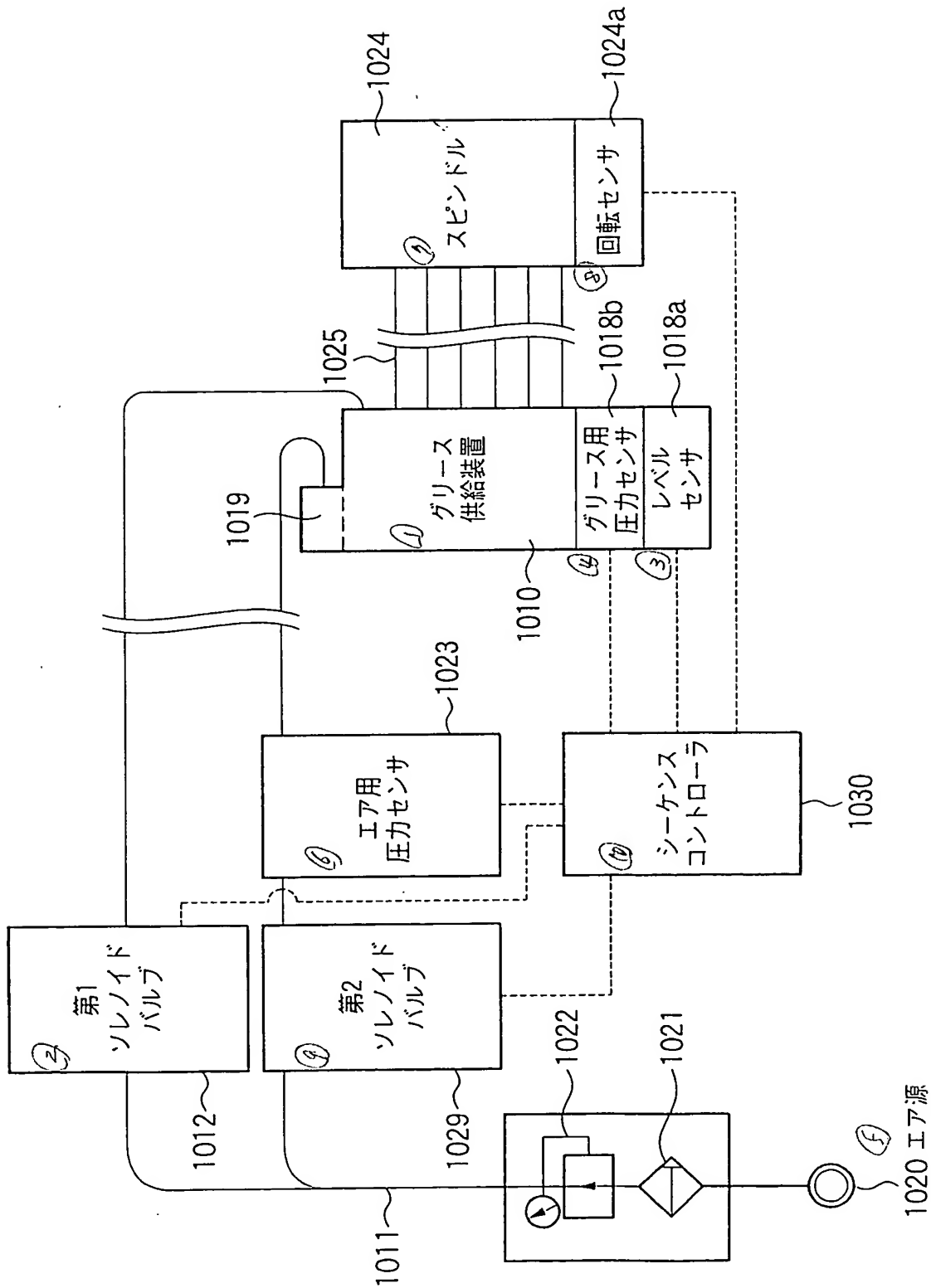


図 63

①

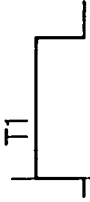
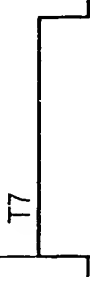
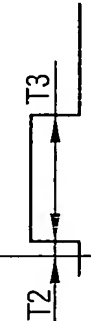
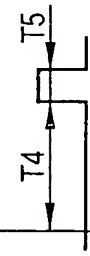
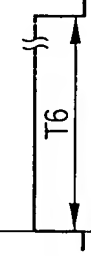
名称	作動タイミングと監視時間	③ 動作		④ 内容
		動作		
⑤ 第2ソレノイドバルブ	ON 	—	—	—
⑥ 第1ソレノイドバルブ	ON 	—	—	—
⑦ エア用圧力センサ	ON 	OFF	⑩ エア圧力低下	
⑧ グリース用圧力センサ	ON 	OFF	⑪ グリースタンク 圧力低下	
⑨ レベルセンサ	ON 	ON	⑫ グリースタンク 残存量不足	

図 64

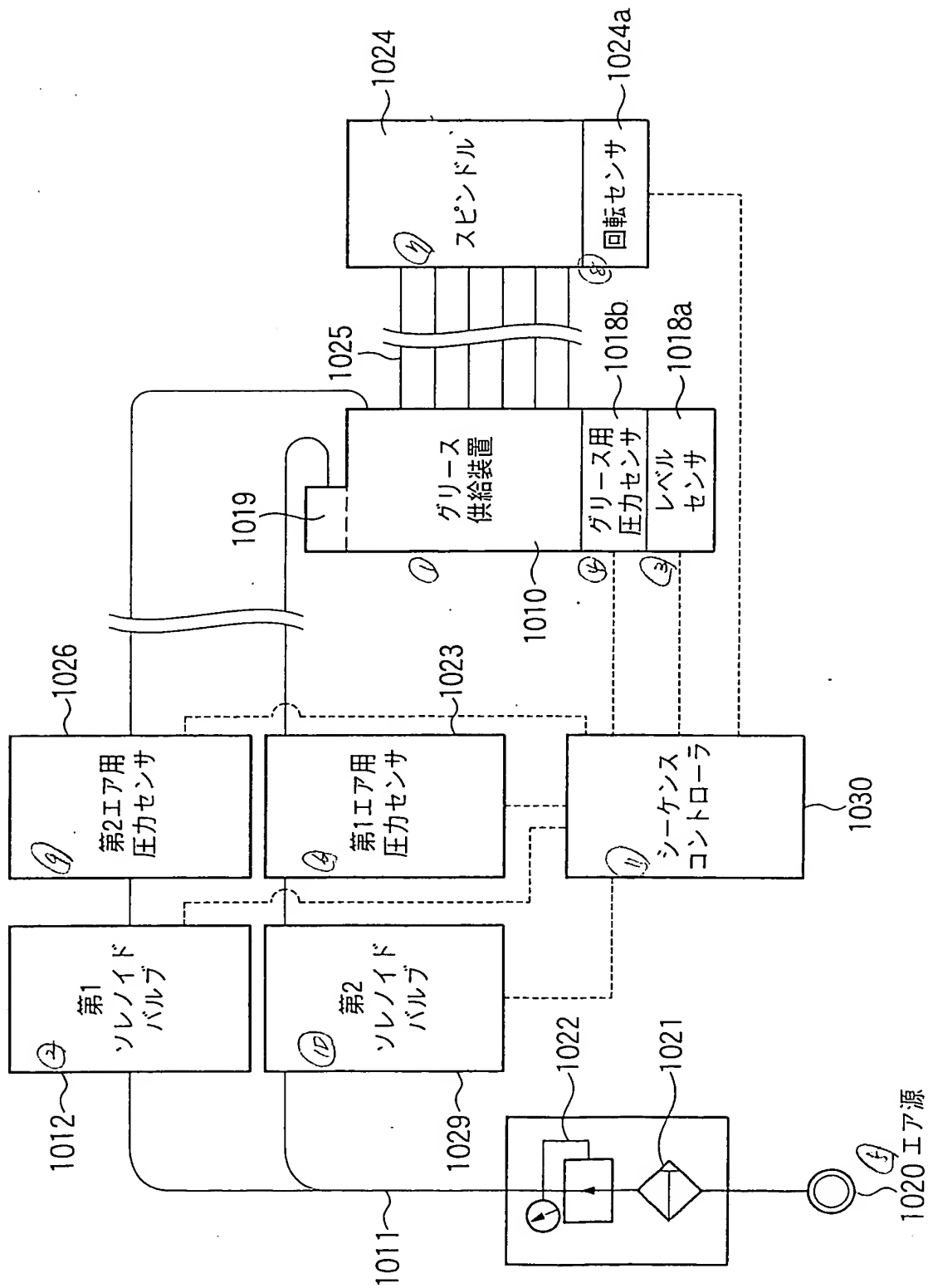


図 65

①

②

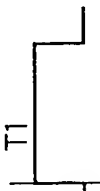

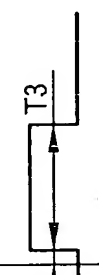
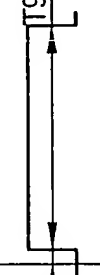
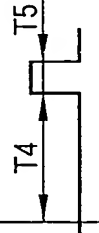
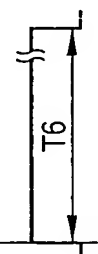
① 名称	② 作動タイミングと監視時間	③		④ 内容
		動作		
⑤ 第2ソレノイドバルブ	ON 	—	—	—
⑥ 第1ソレノイドバルブ	ON 	—	—	—
⑦ 第1エア用圧力センサ	ON 	OFF	⑪ エア圧力低下	
⑧ 第2エア用圧力センサ	ON 	OFF	⑪ エア圧力低下	
⑨ グリース用圧力センサ	ON 	OFF	⑬ グリースタンク 圧力低下	
⑩ レベルセンサ	ON 	ON	⑭ グリースタンク 残存量不足	

図 66

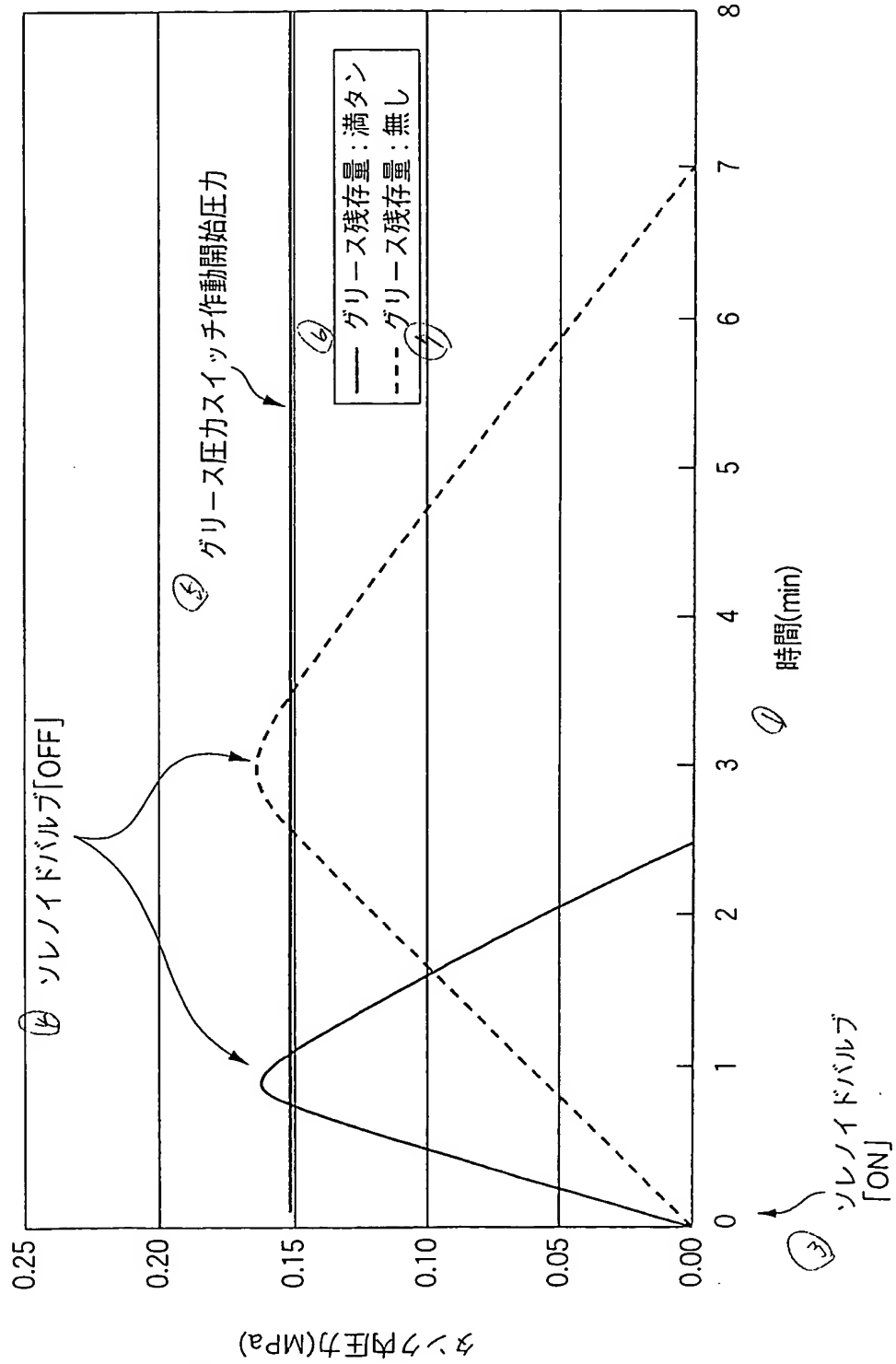


图 67

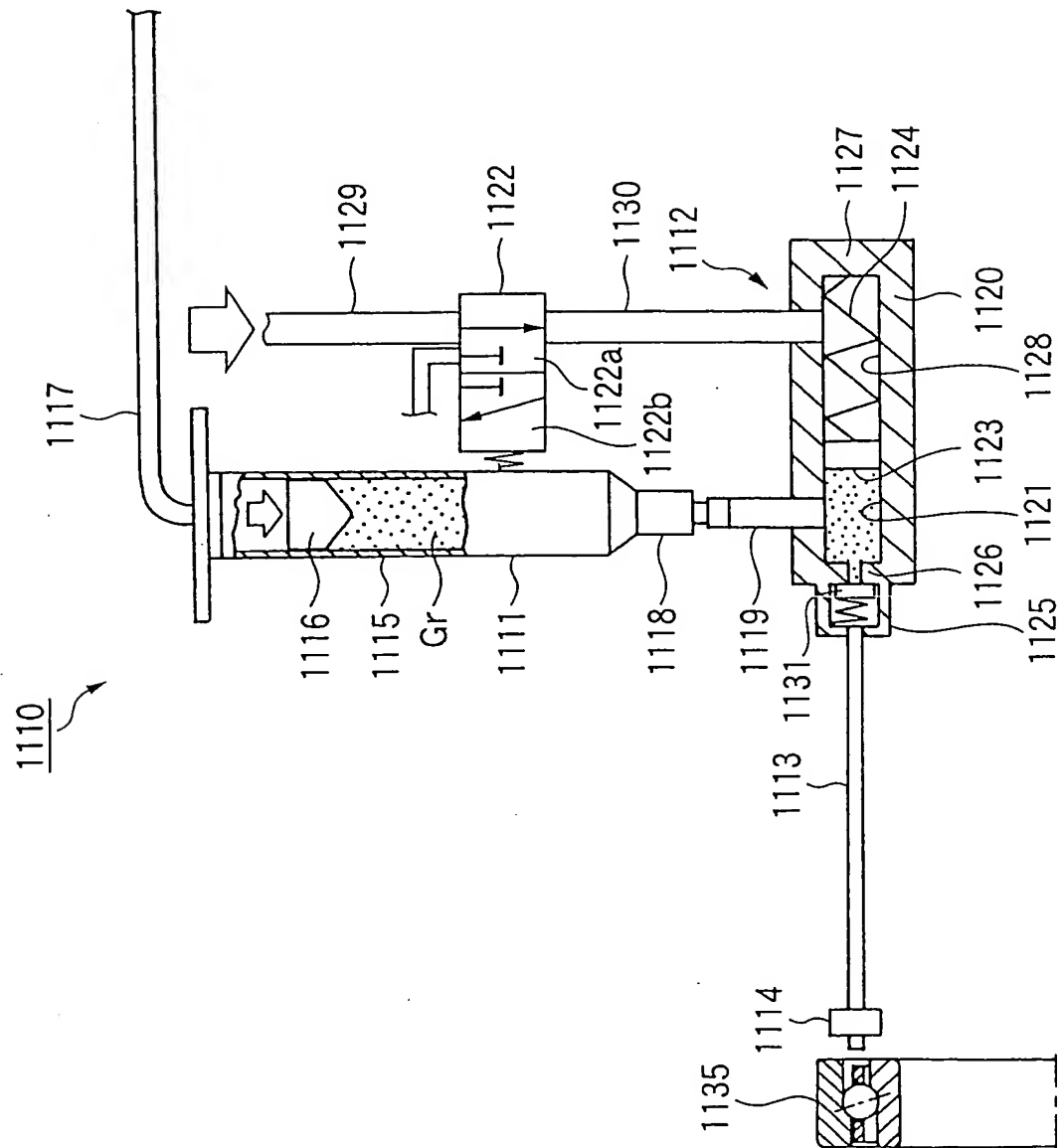


図 68

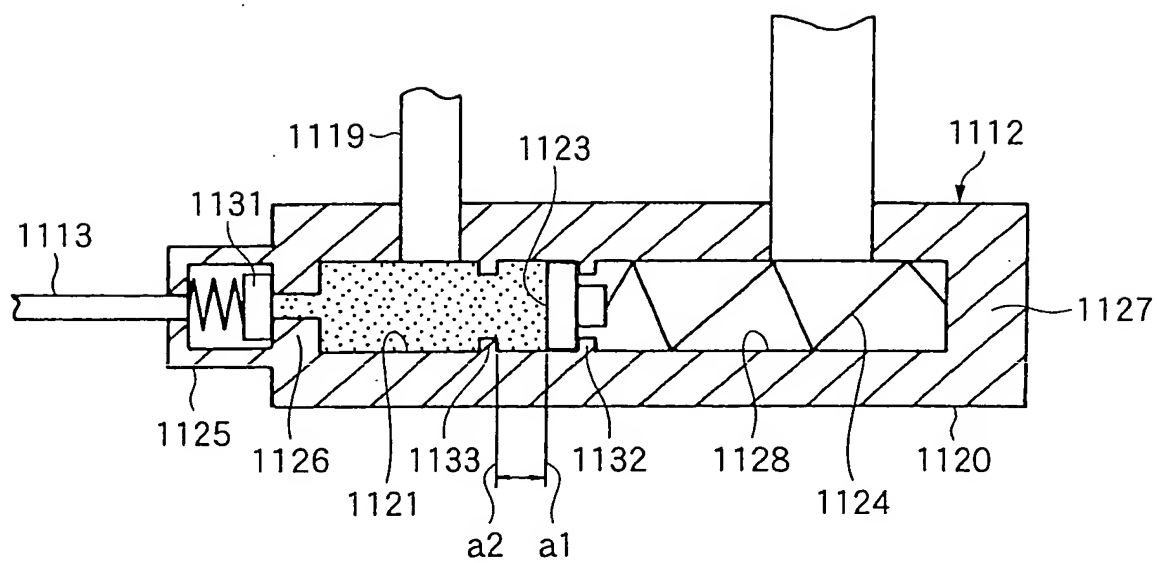


図 69

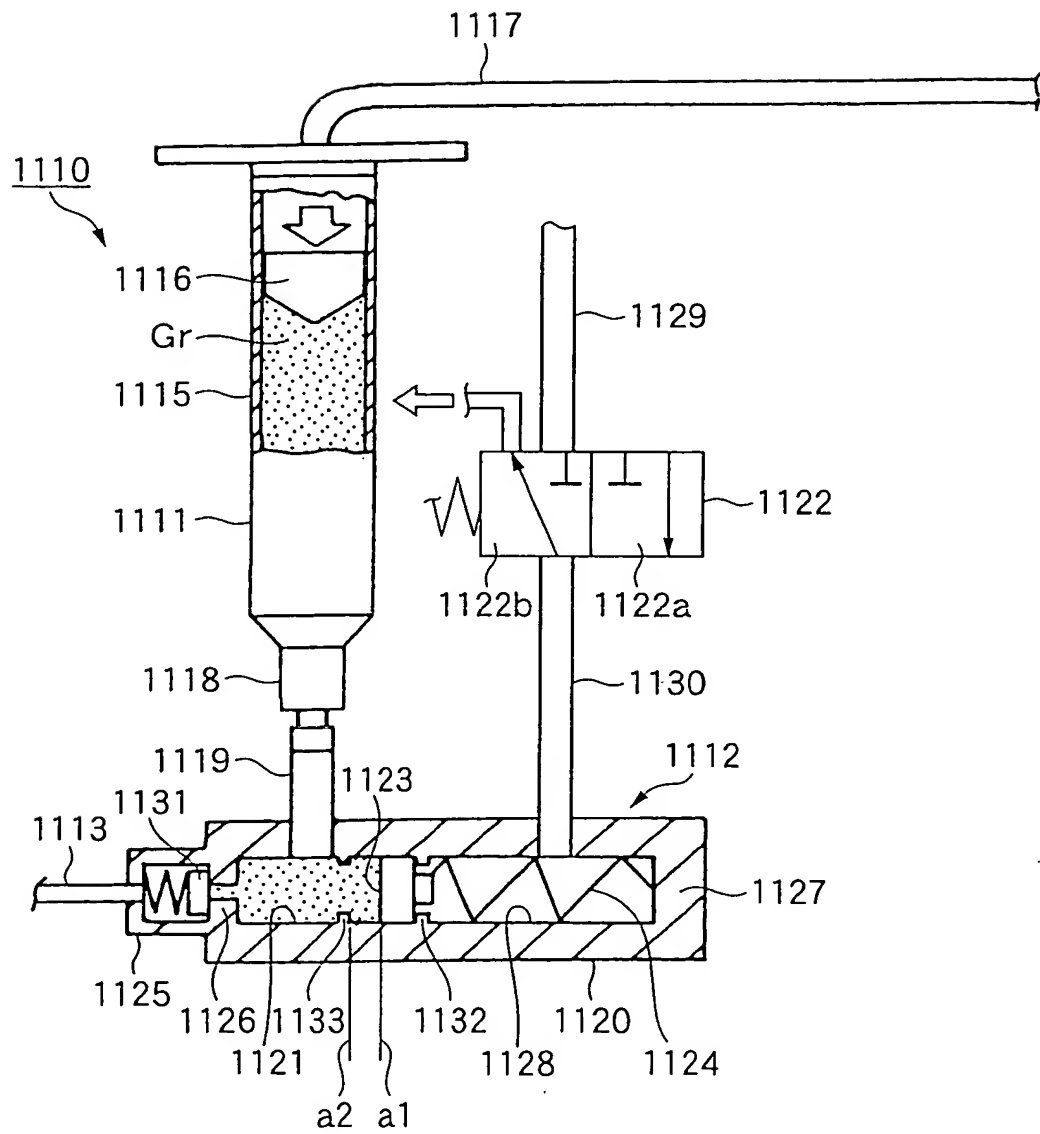


図 70

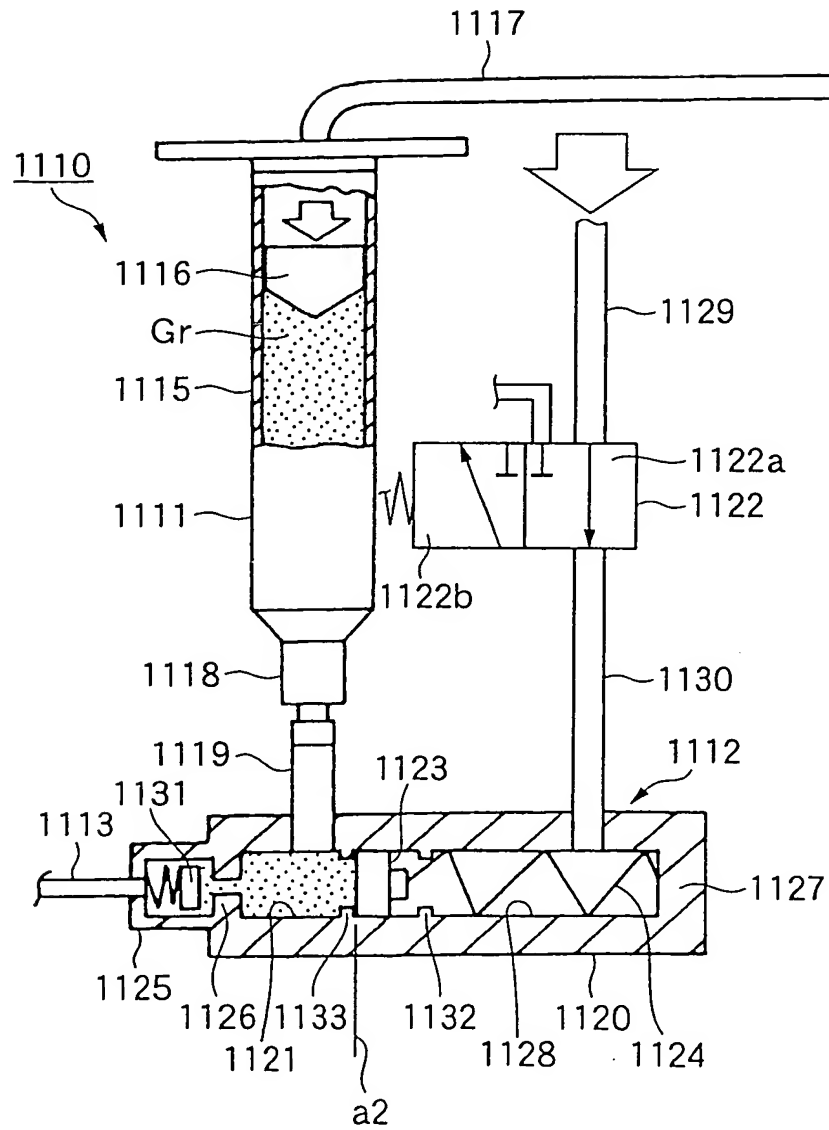


図 72

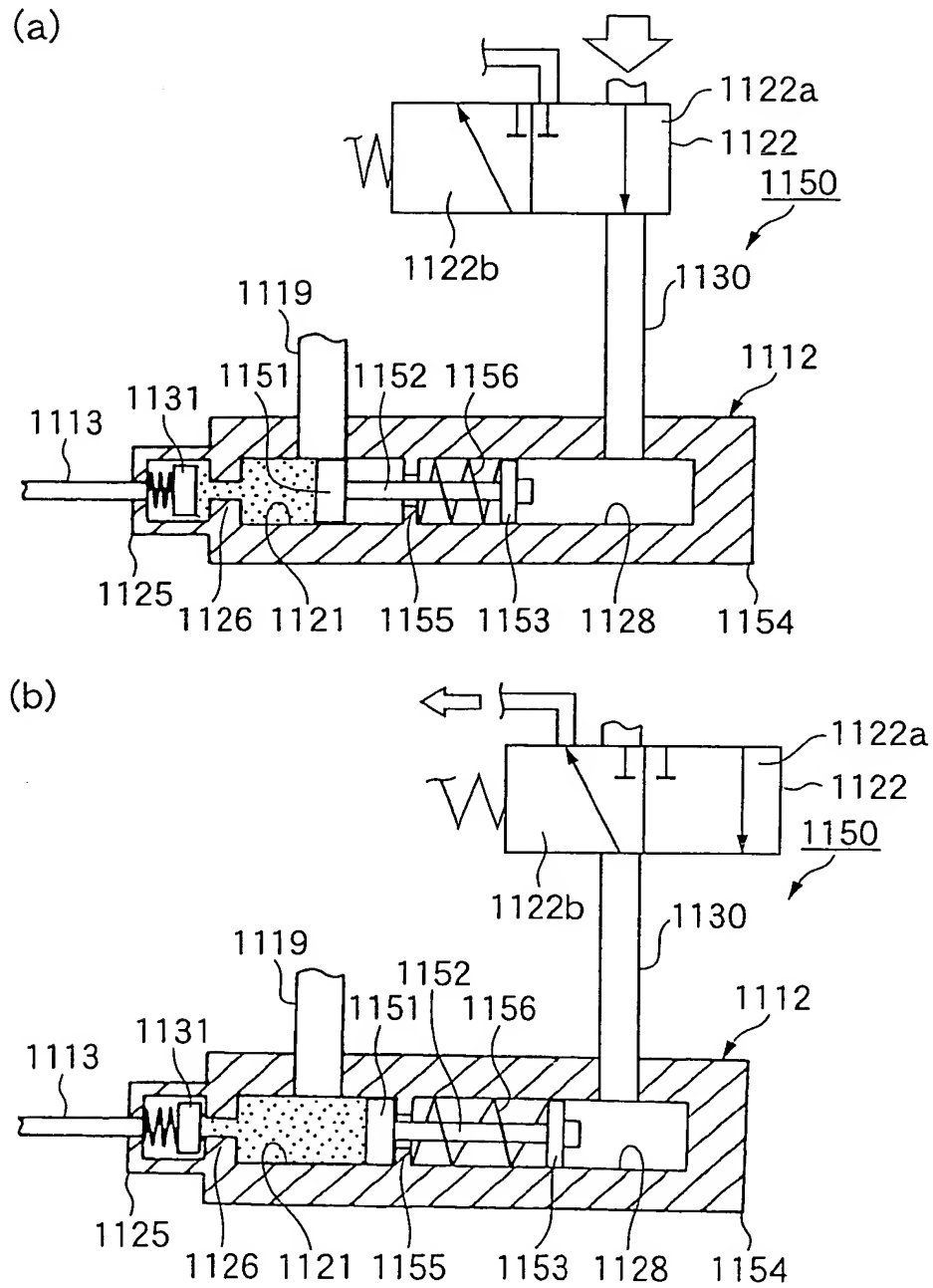
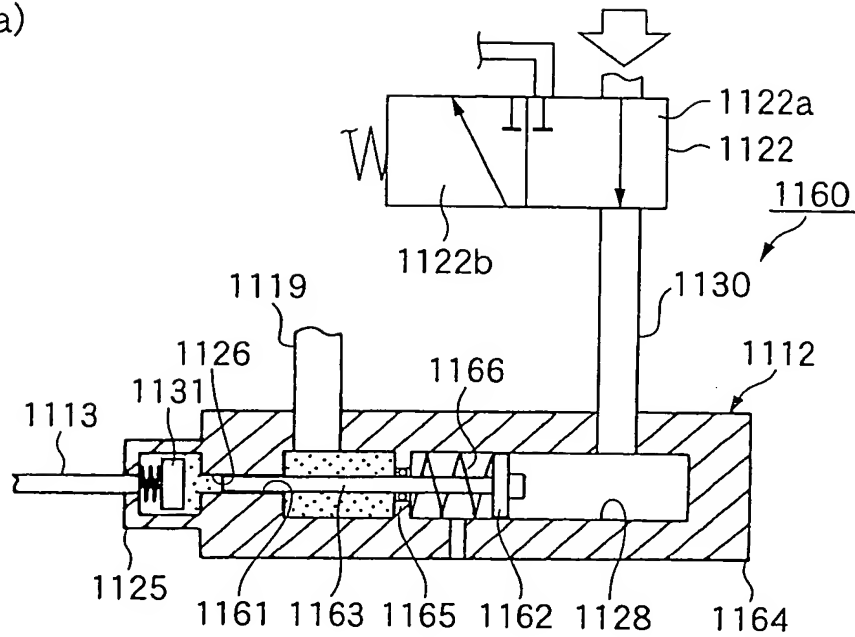


図 73

(a)



(b)

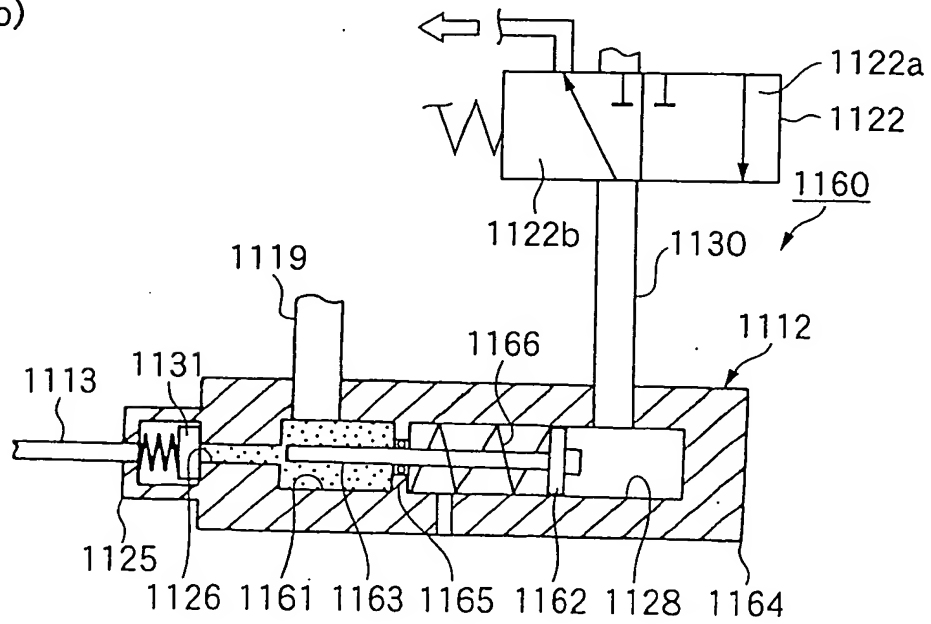


図 74

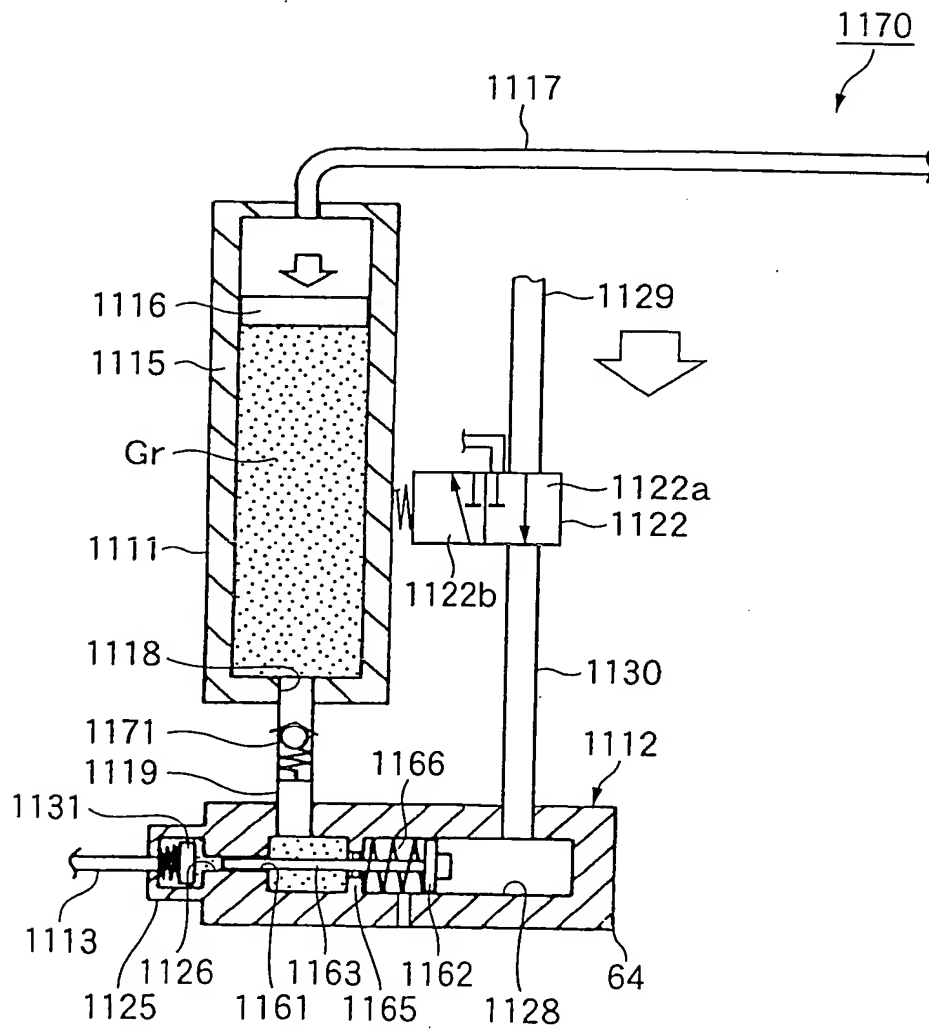


図 75

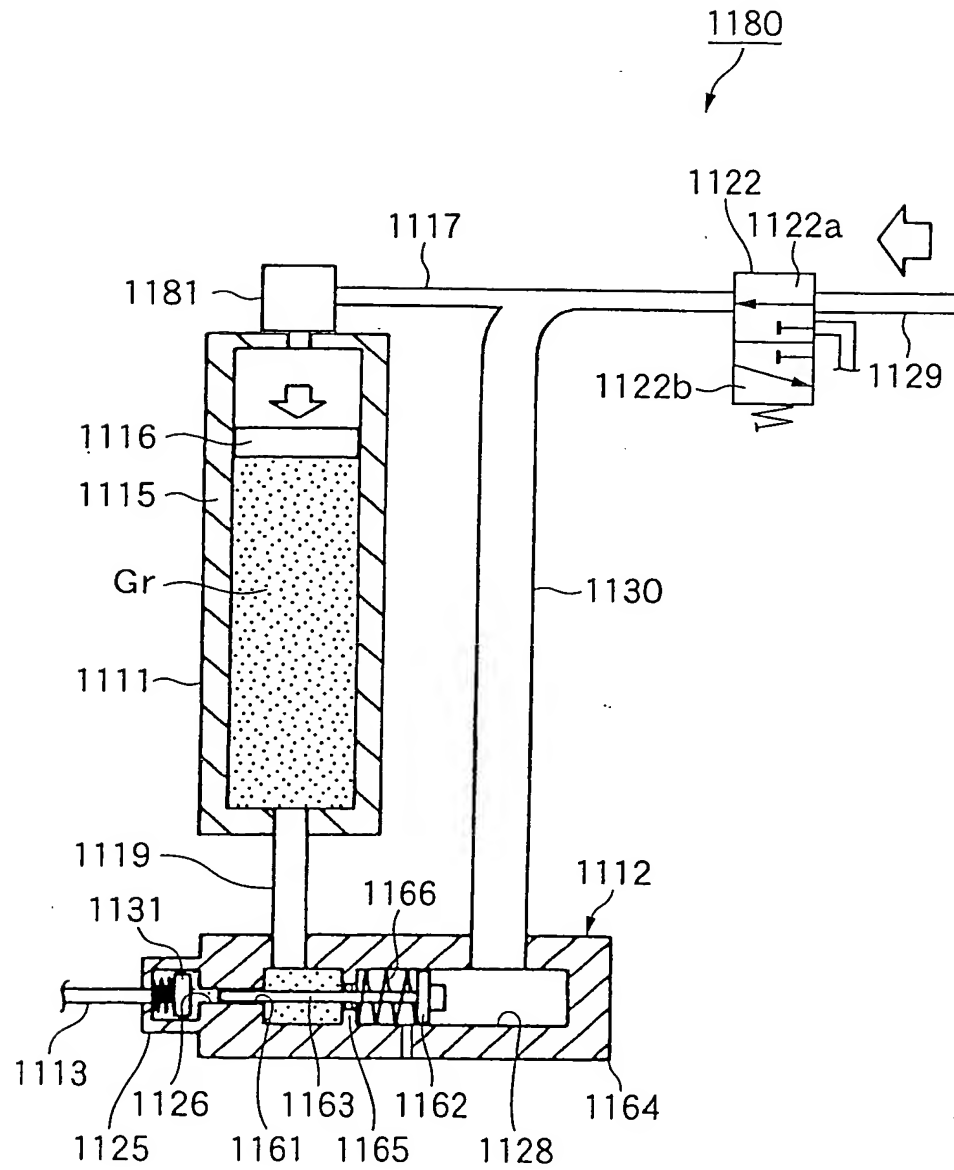


図 76

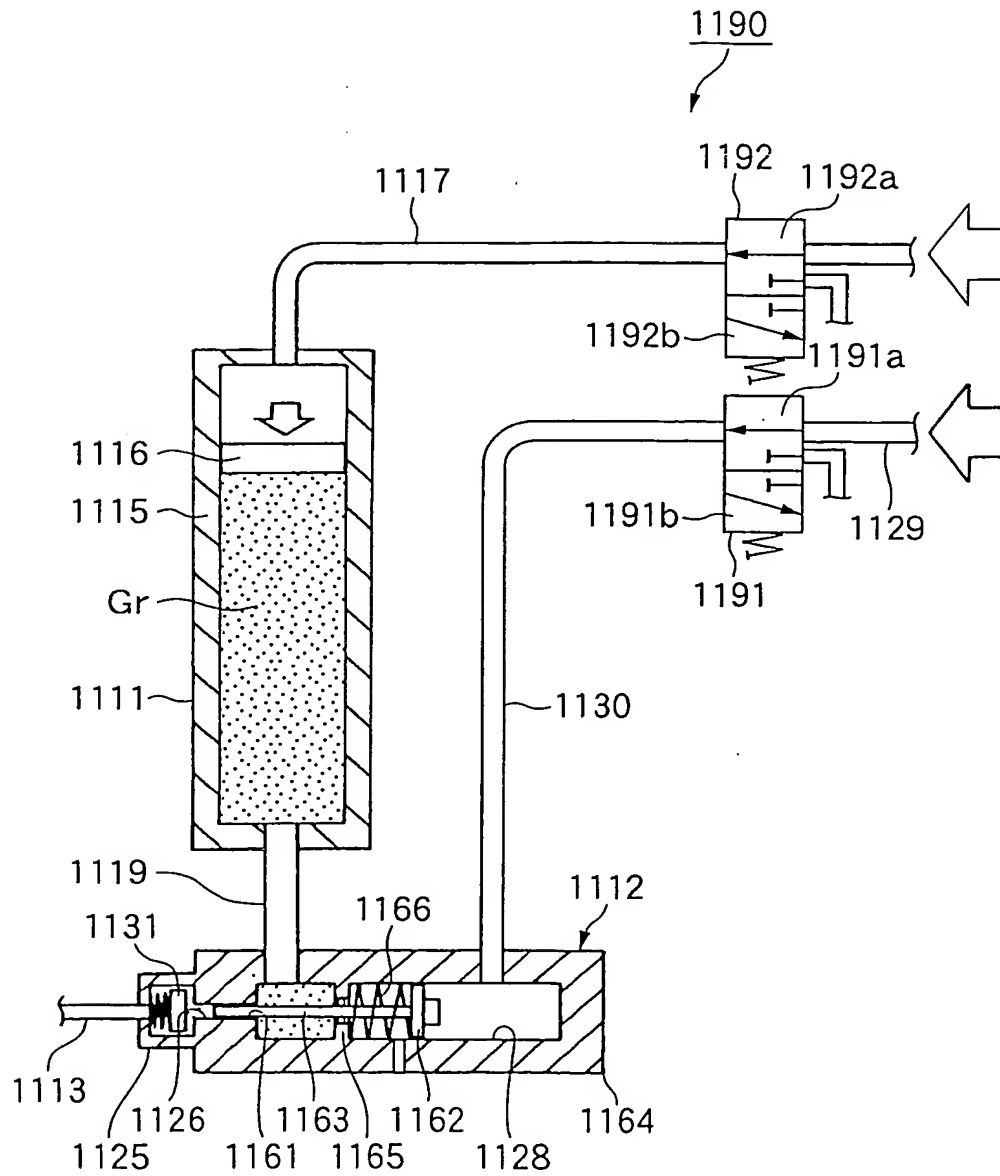


図 77

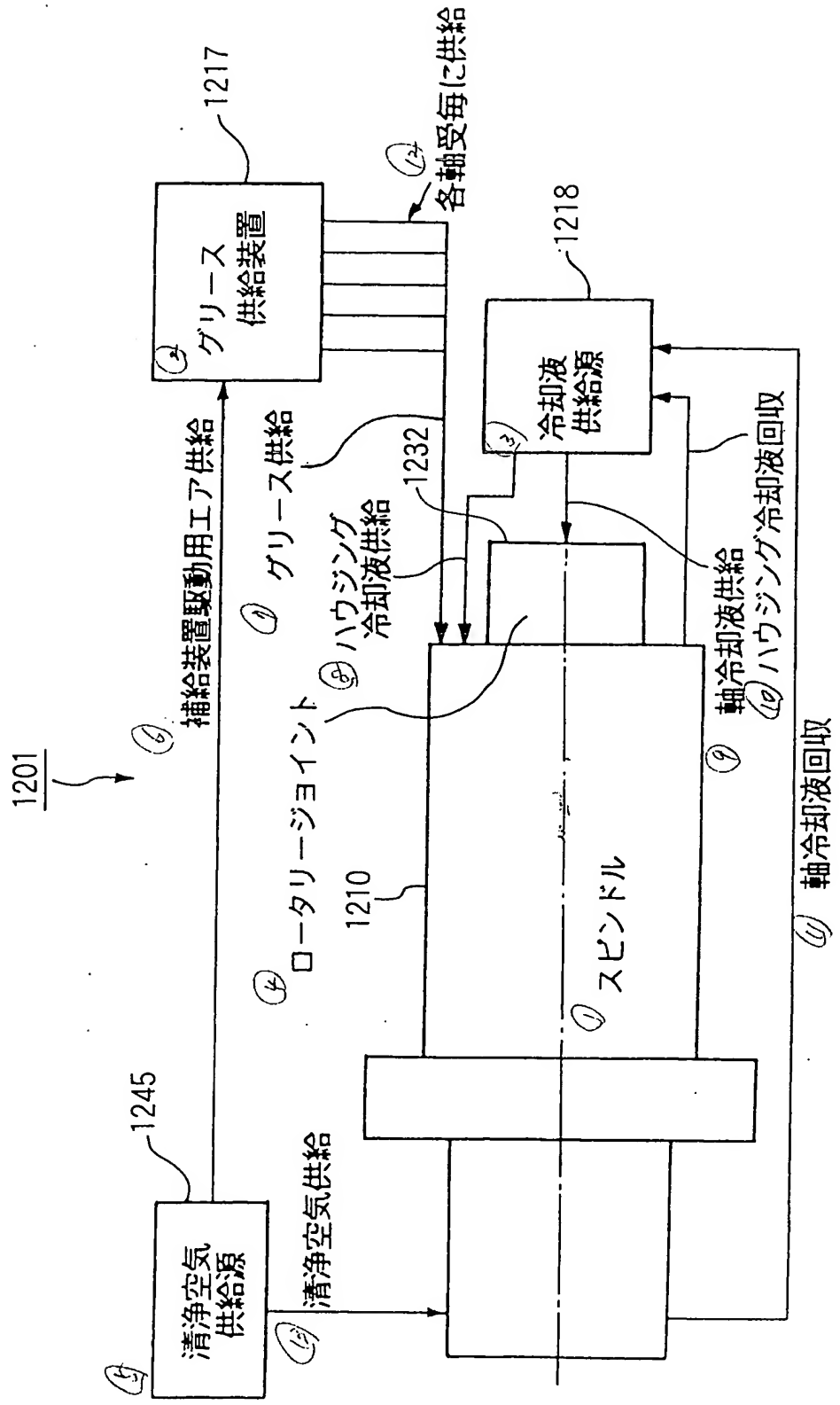


図 78

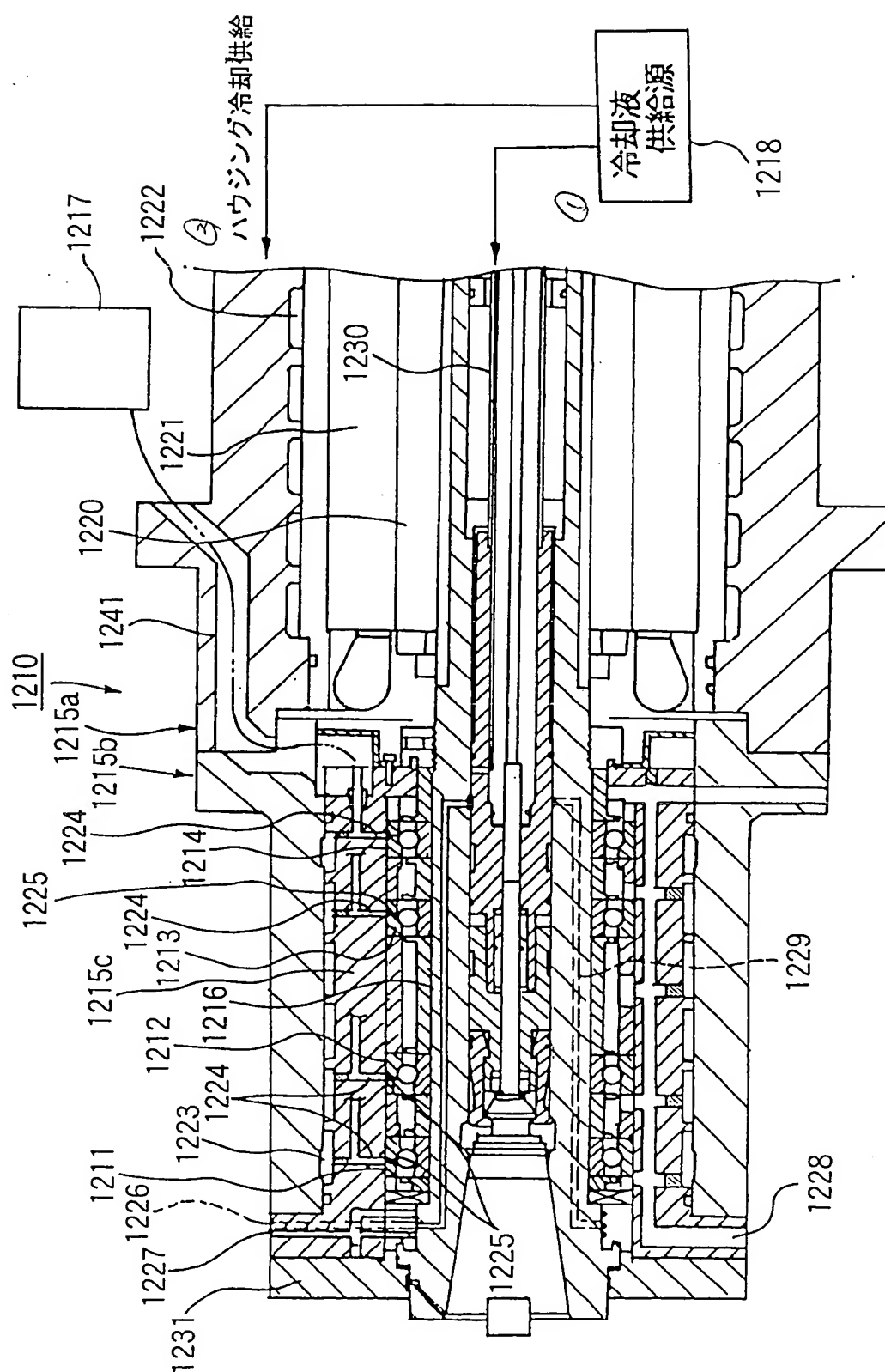


図 79

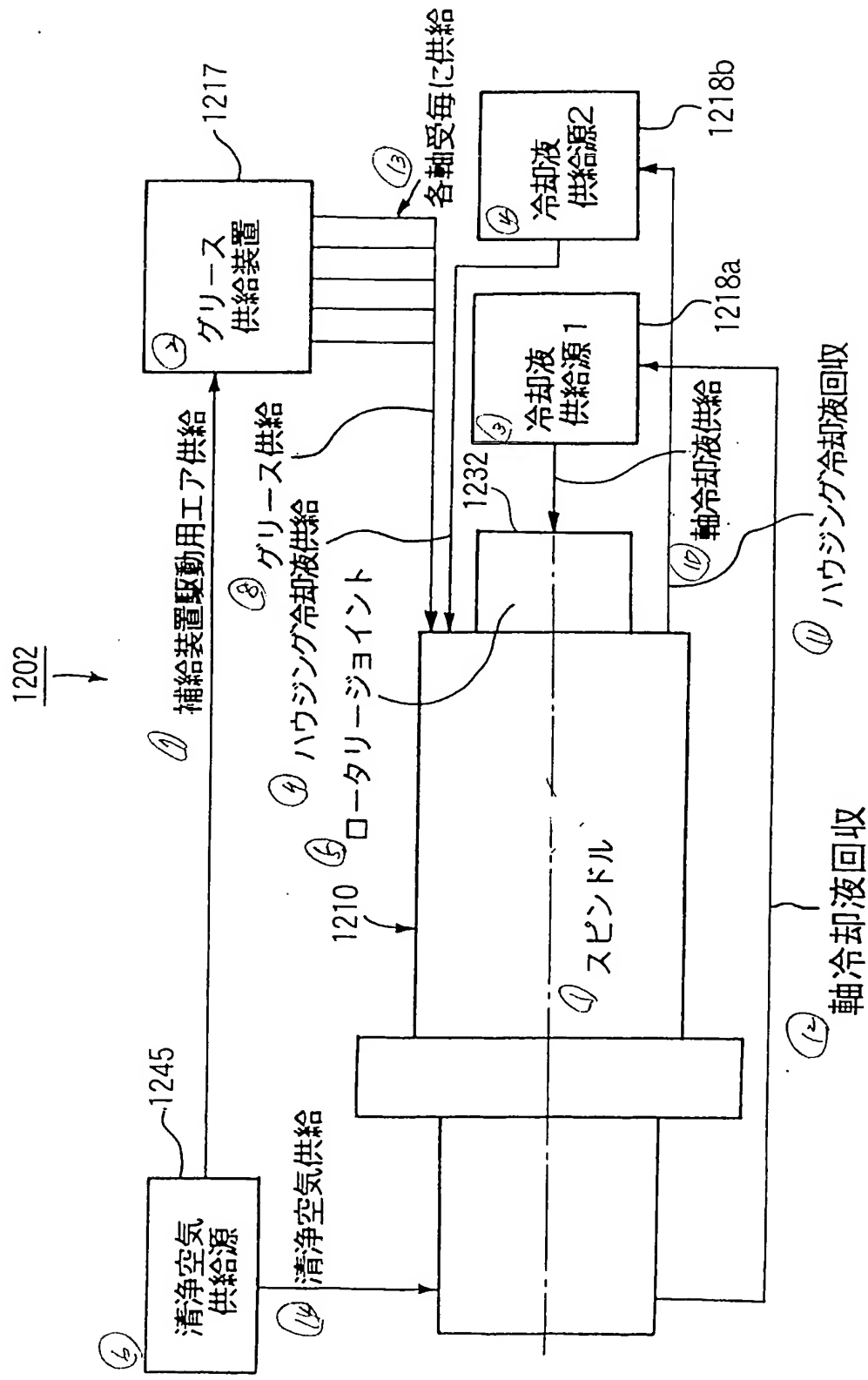


図 81

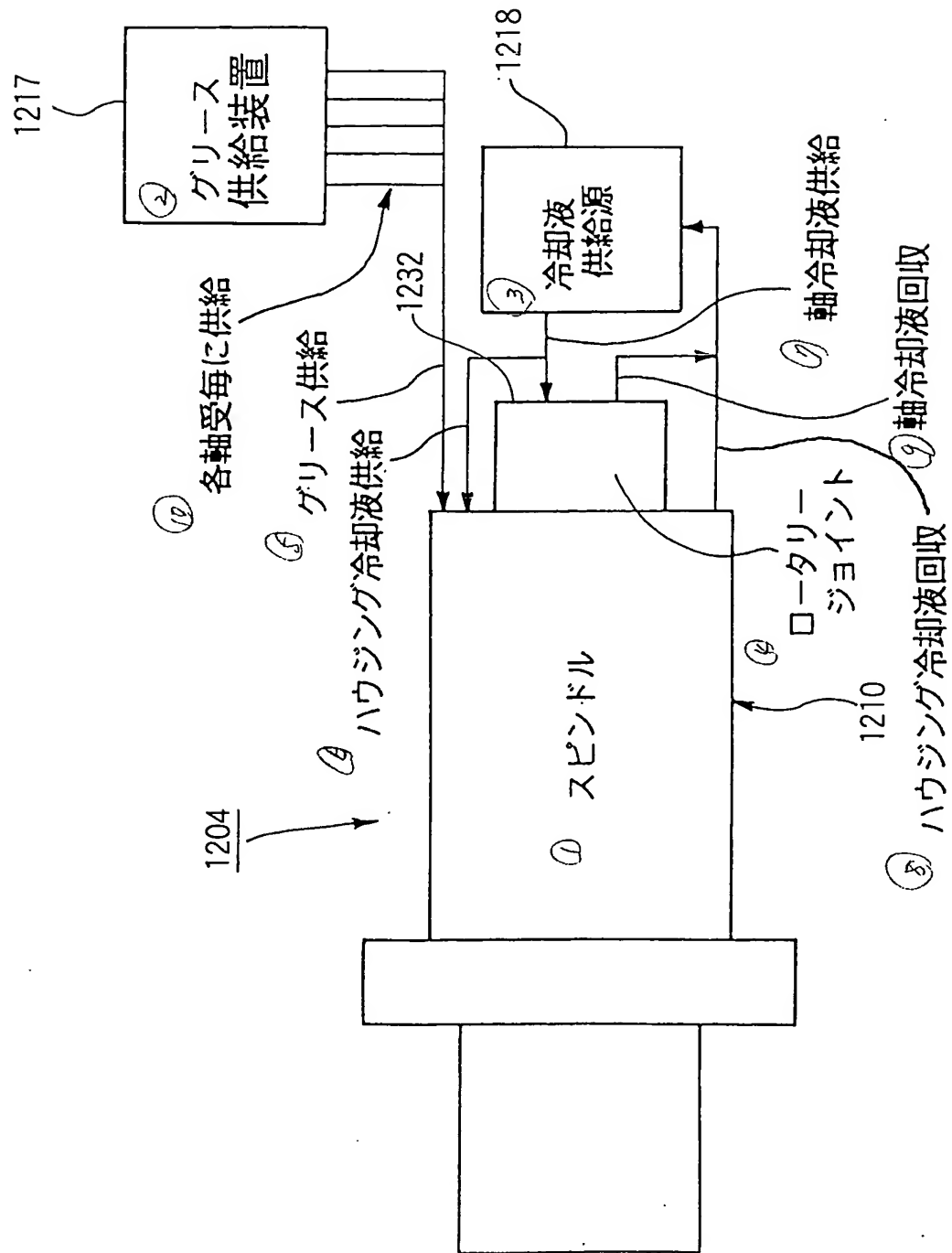


図 82

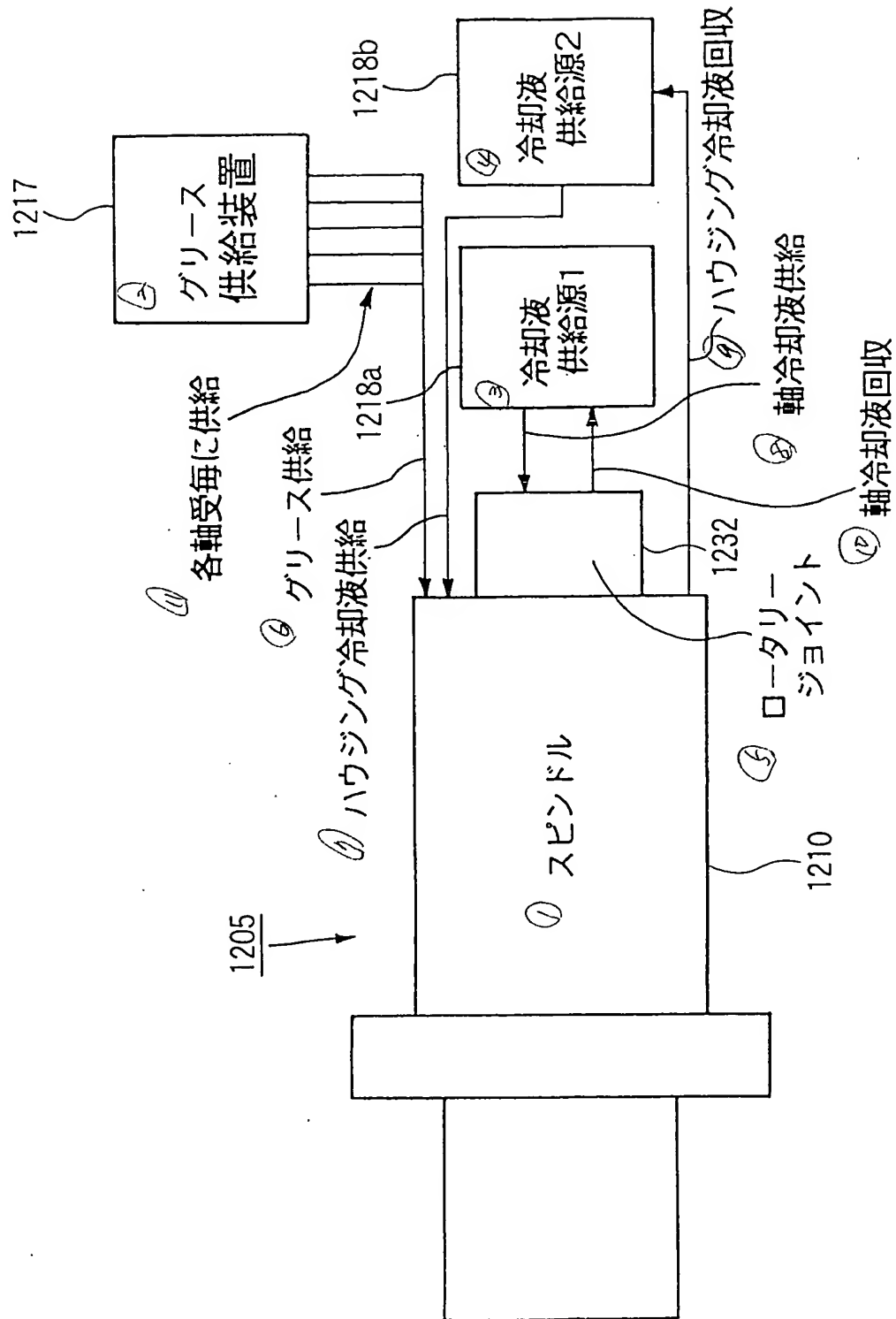


図 83

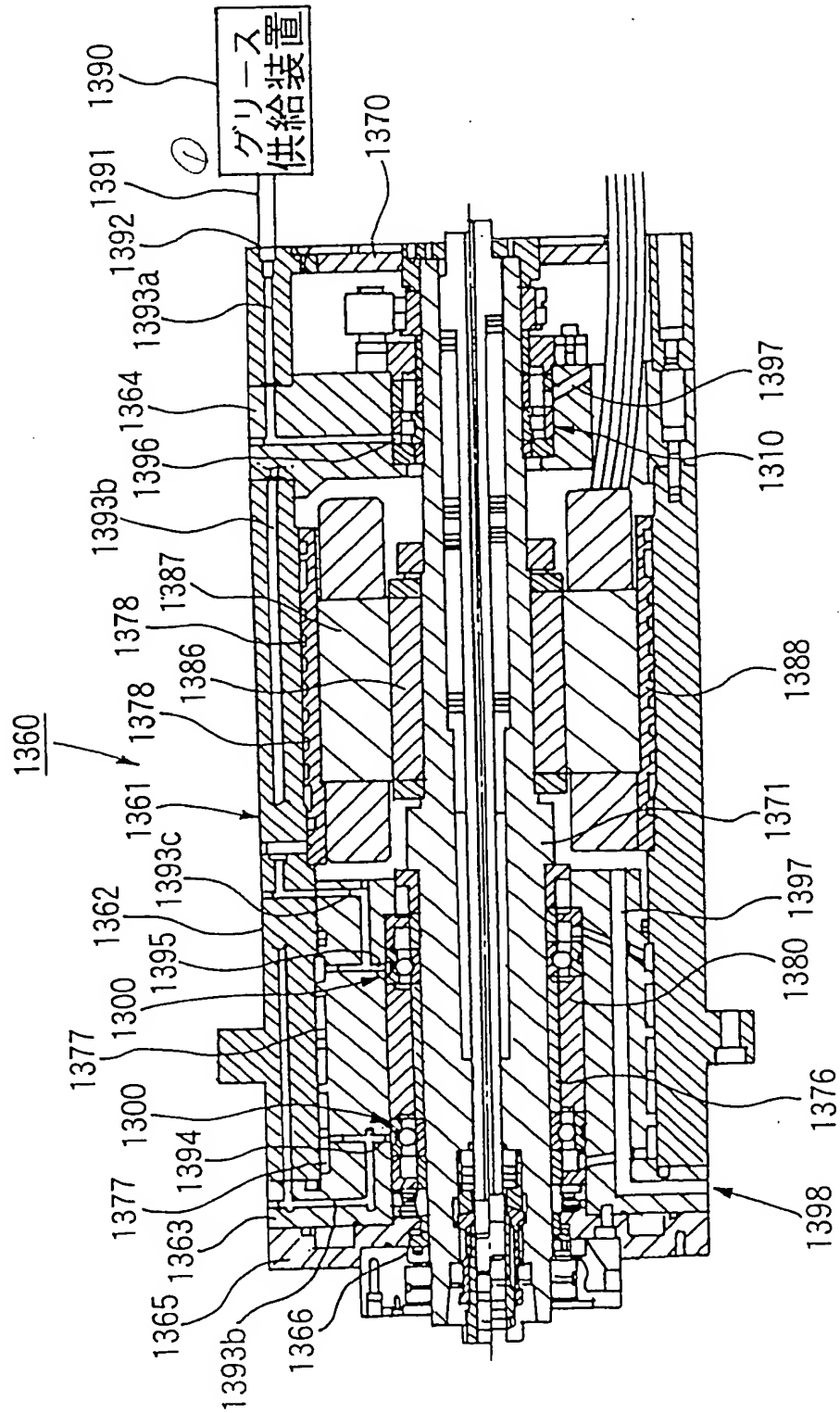
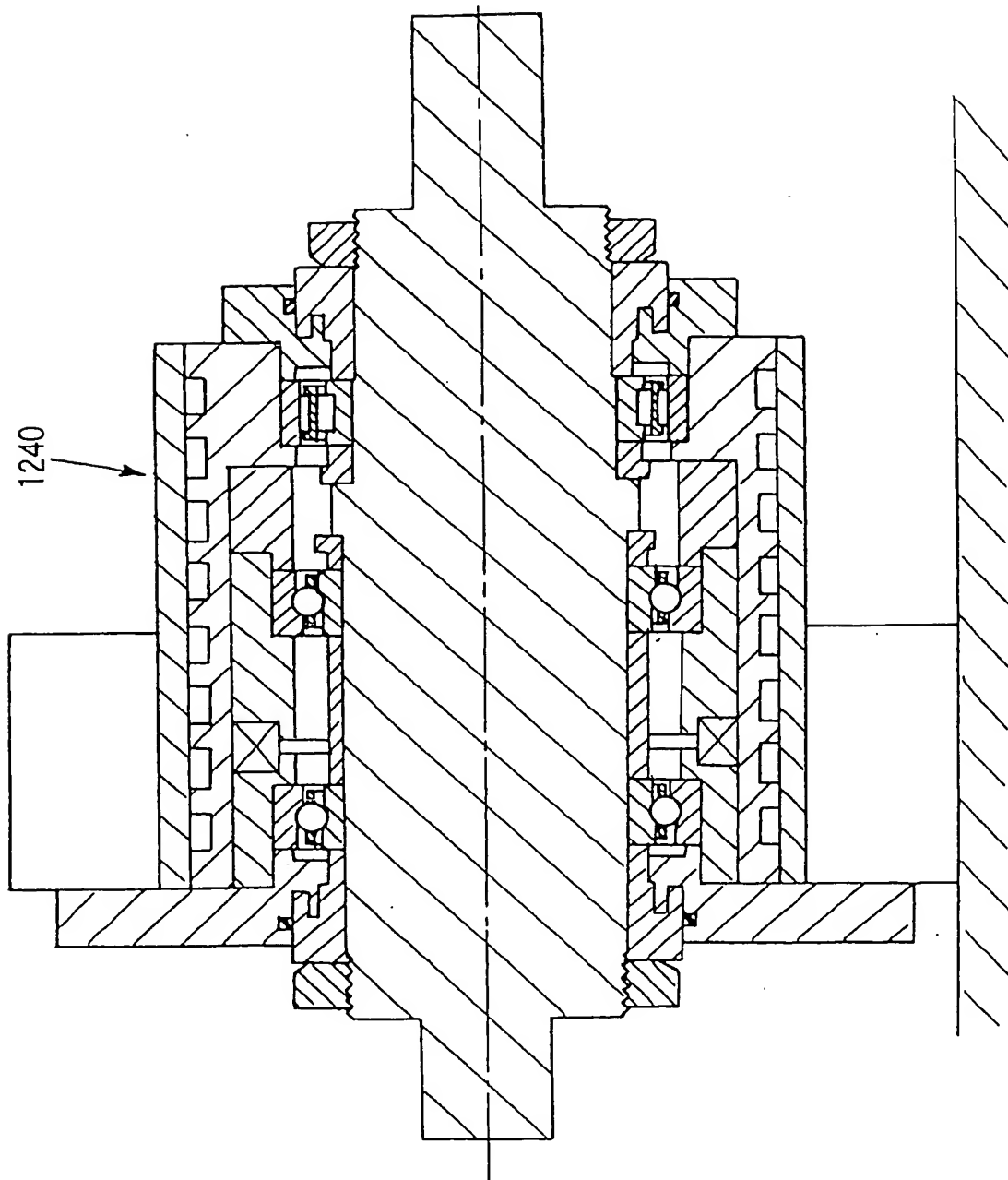



図 84



 85

① 試験No	1	2	3
② 定圧予圧荷重(N)	1870	1870	1870
③ 初期グリース封入量(%)	1	5	15
④ 初期グリース封入量(cc)	0.15	0.75	2.25
⑤ 冷却(冷却油温度)	⑧ あり(25°C)	⑧ あり(25°C)	⑧ あり(25°C)
⑥ 軸受温度(°C)	42	42	42
⑦ 耐久時間(hr)	28.5	118.5	260

図 86

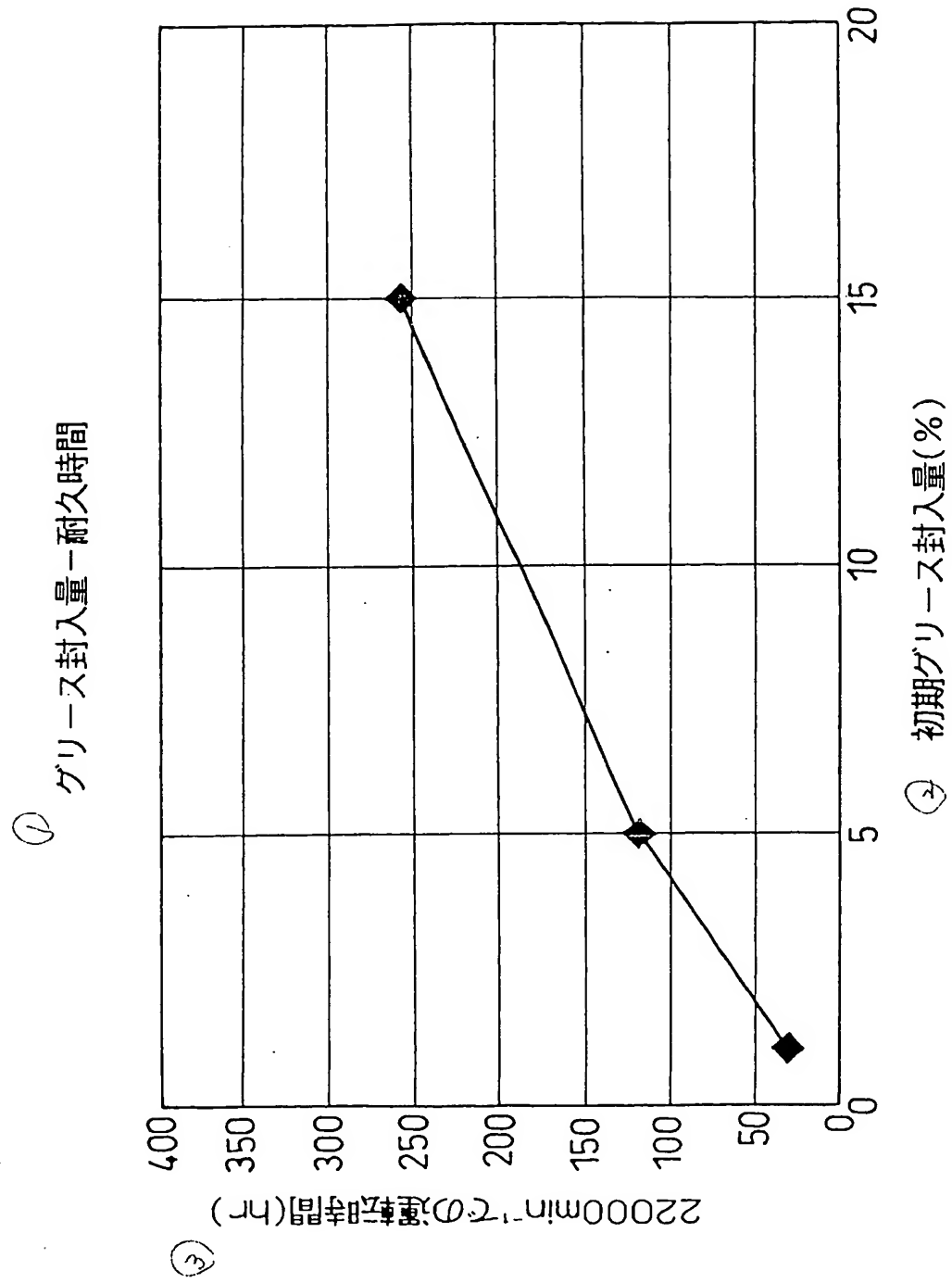


図 87

① 試験 No.	1	4	5
② 定圧予圧荷重(N)	1870	1870	1870
③ 初期グリース封入量(%)	1	1	1
④ 初期グリース封入量(cc)	0.15	0.15	0.15
⑤ 冷却(冷却油温度)	⑧ あり(25°C)	⑨ あり(20°C)	⑩ なし
⑥ 軸受温度(°C)	42	30	62
⑦ 耐久時間(hr)	28.5	56	8

図 88

① 軸受温度-耐久時間

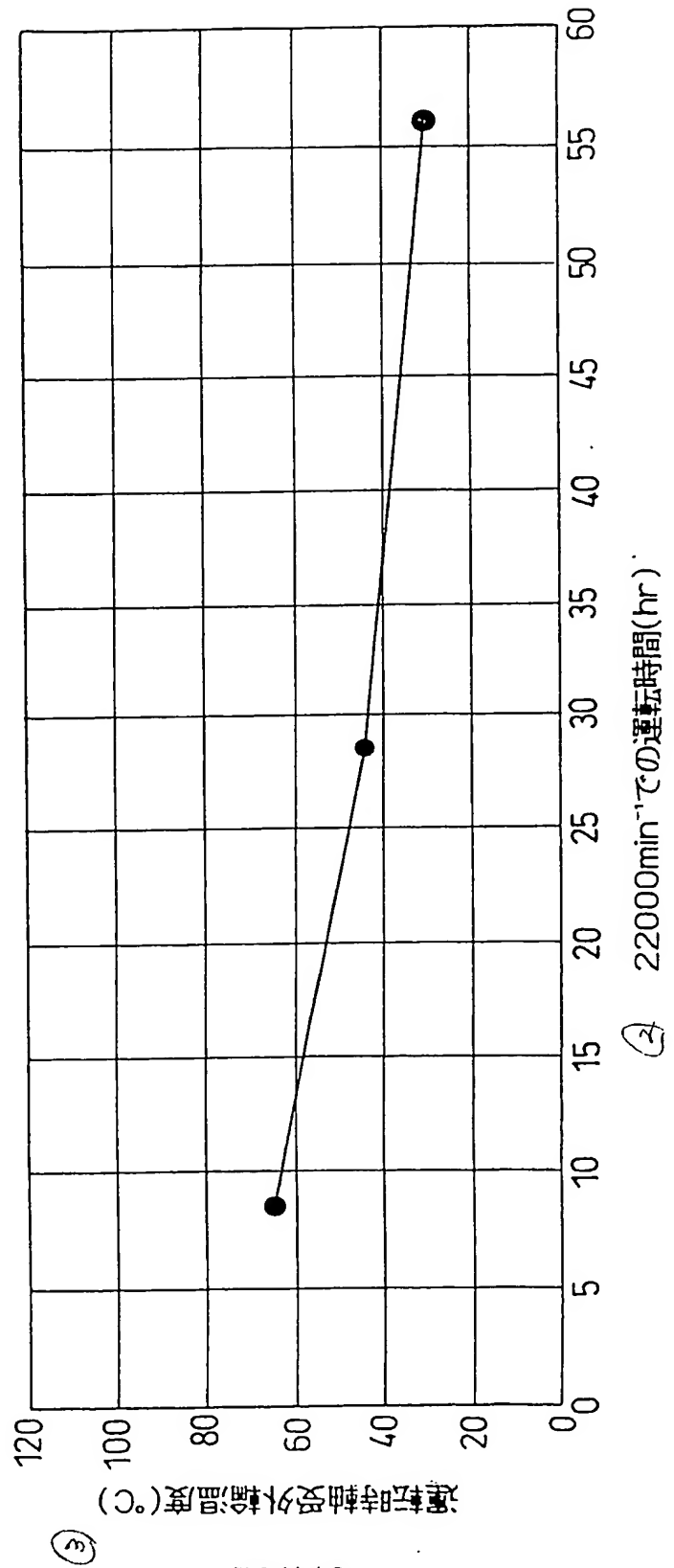


図 89

① 試験 No.	2	6	7	8
② 定圧予圧荷重(N)	1870	2200	2600	3000
③ 初期グリース封入量(%)	5	→	→	→
④ 初期グリース封入量(cc)	0.75	→	→	→
⑤ 冷却(冷却油温度)	あり(25℃)	→	→	→
⑥ 軸受温度(℃)	42	→	→	→
⑦ 耐久時間(hr)	118.5	56	45	29

図 90

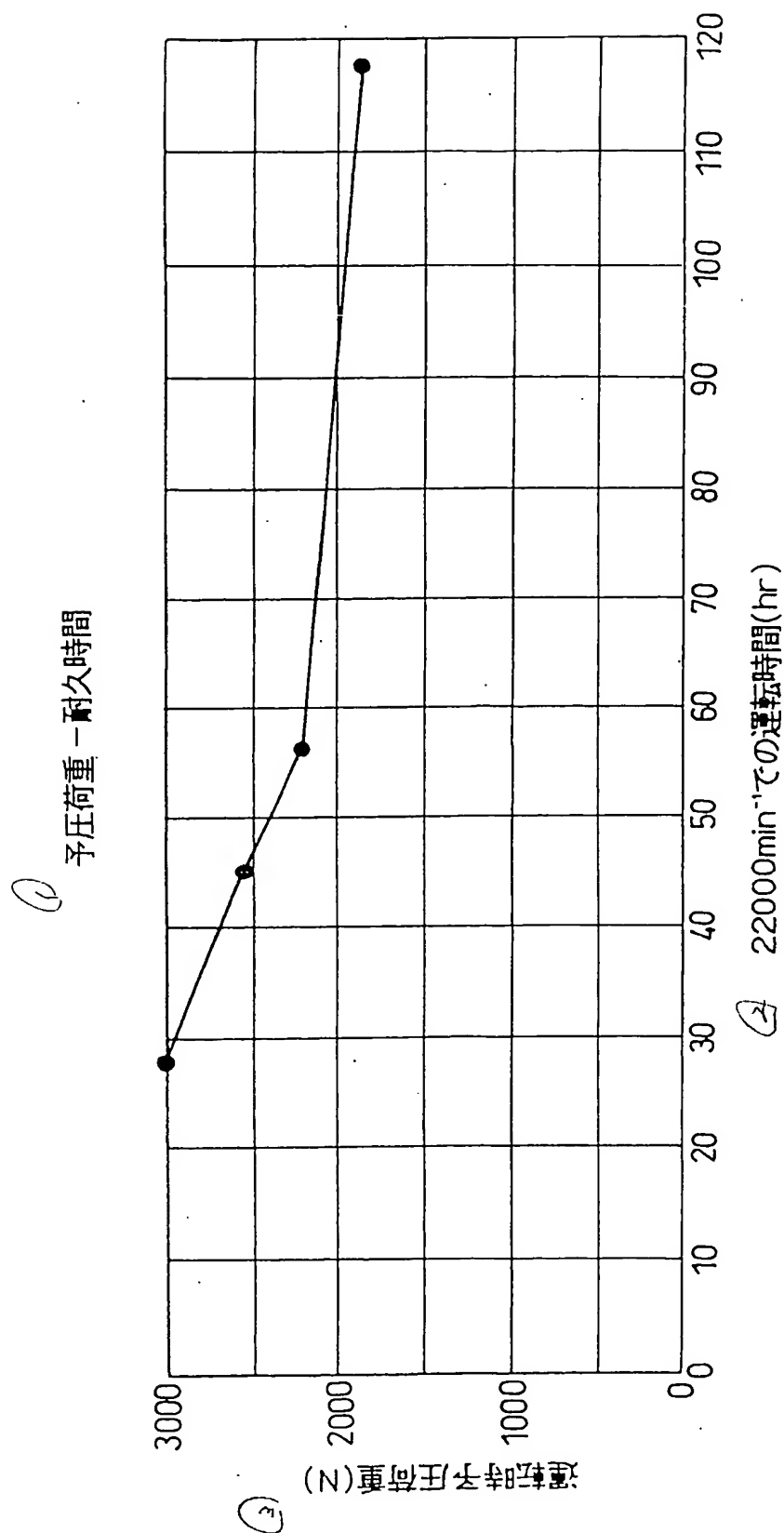


図 91

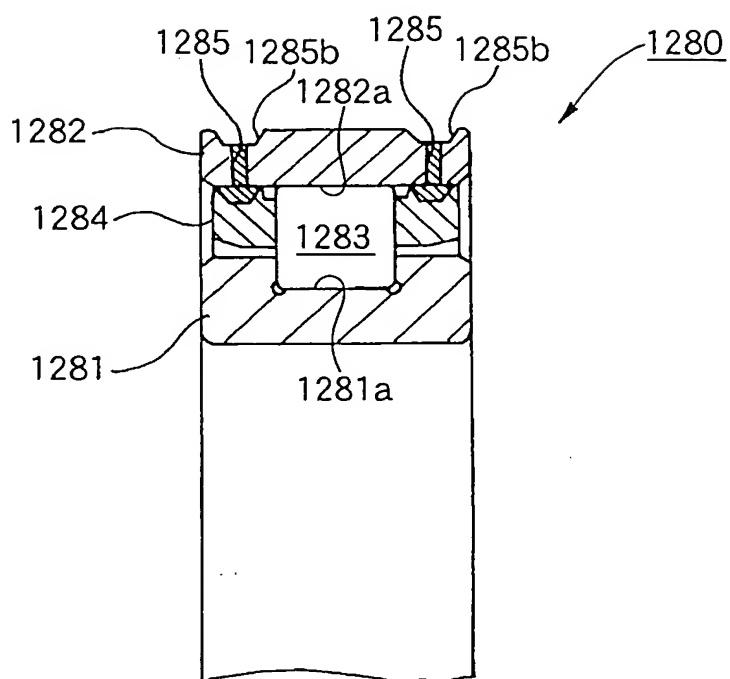


図 92

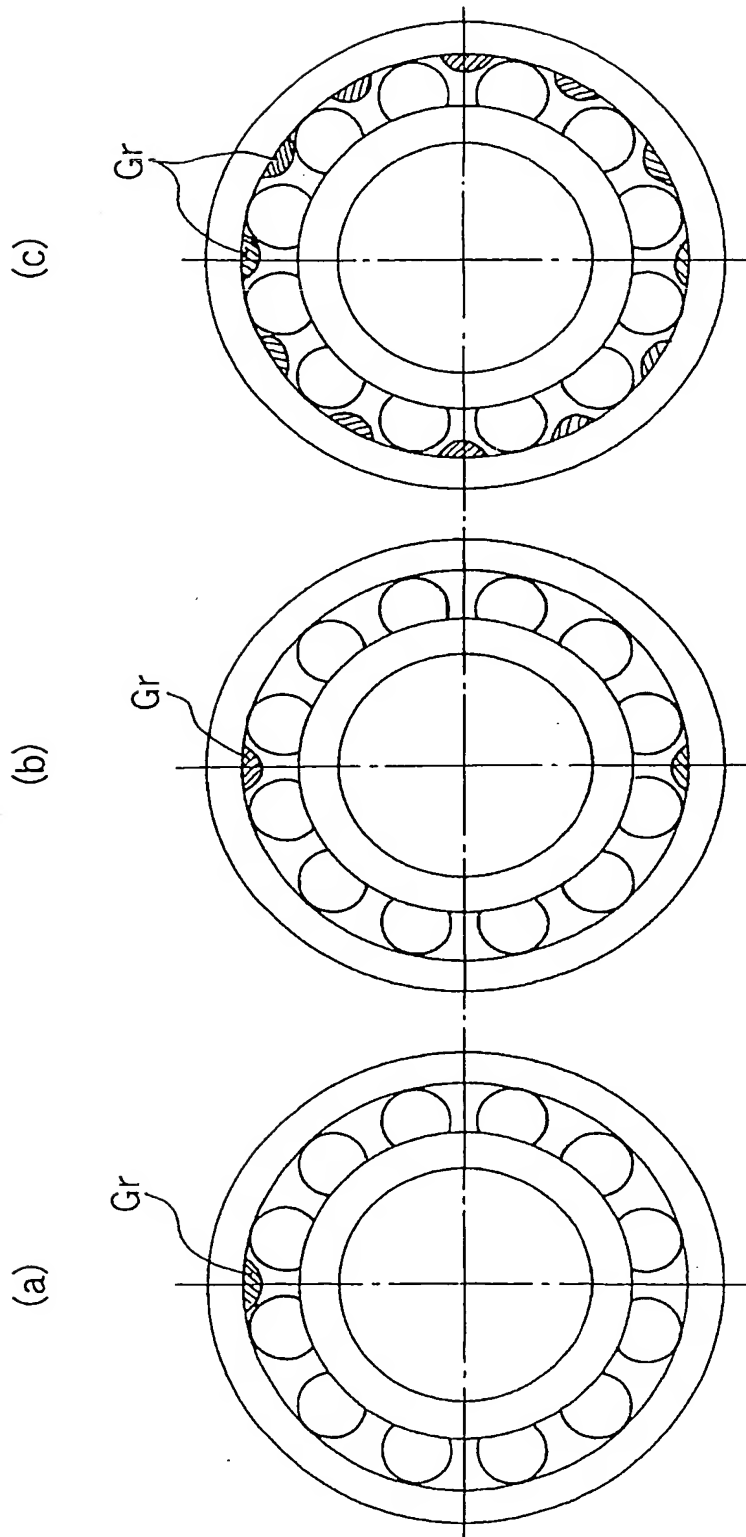


図 93

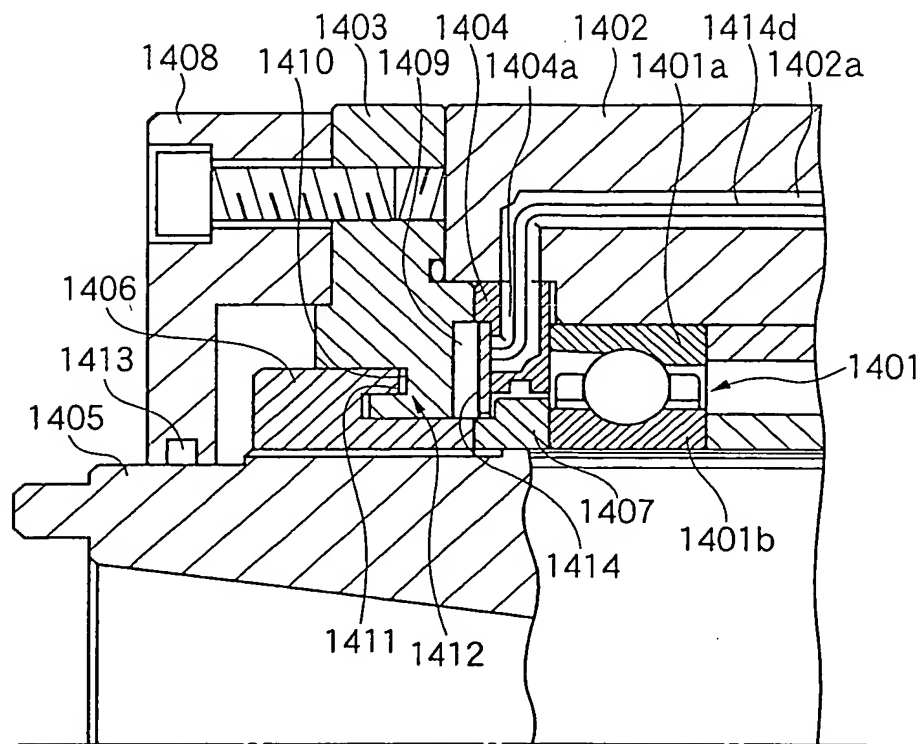


図 94

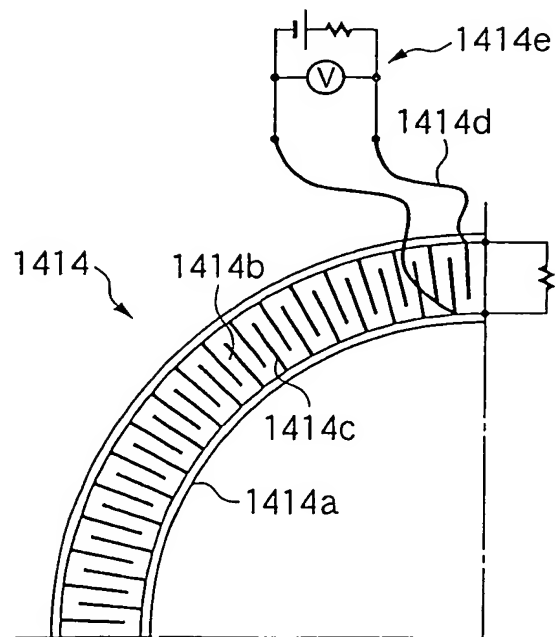


图 95

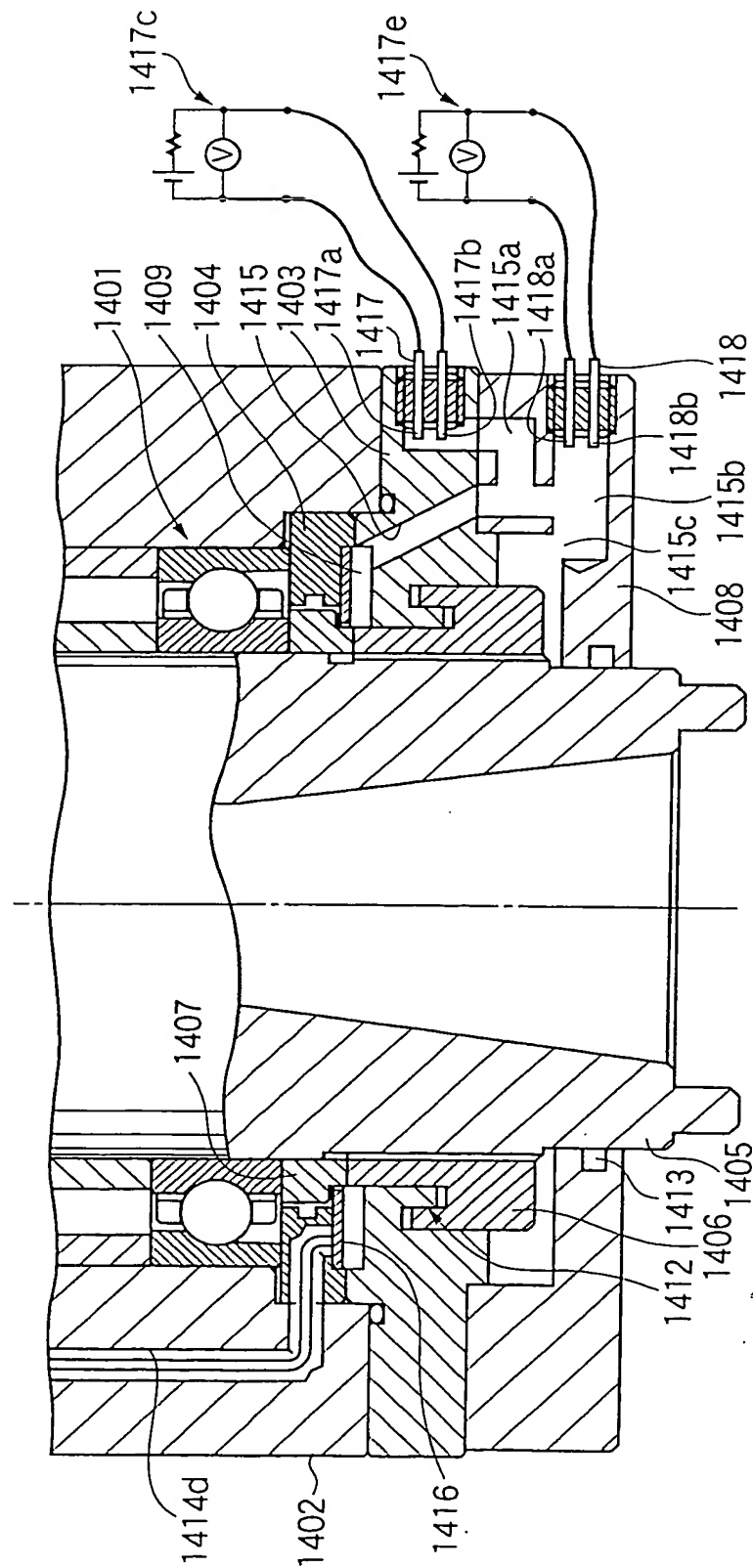


図 96

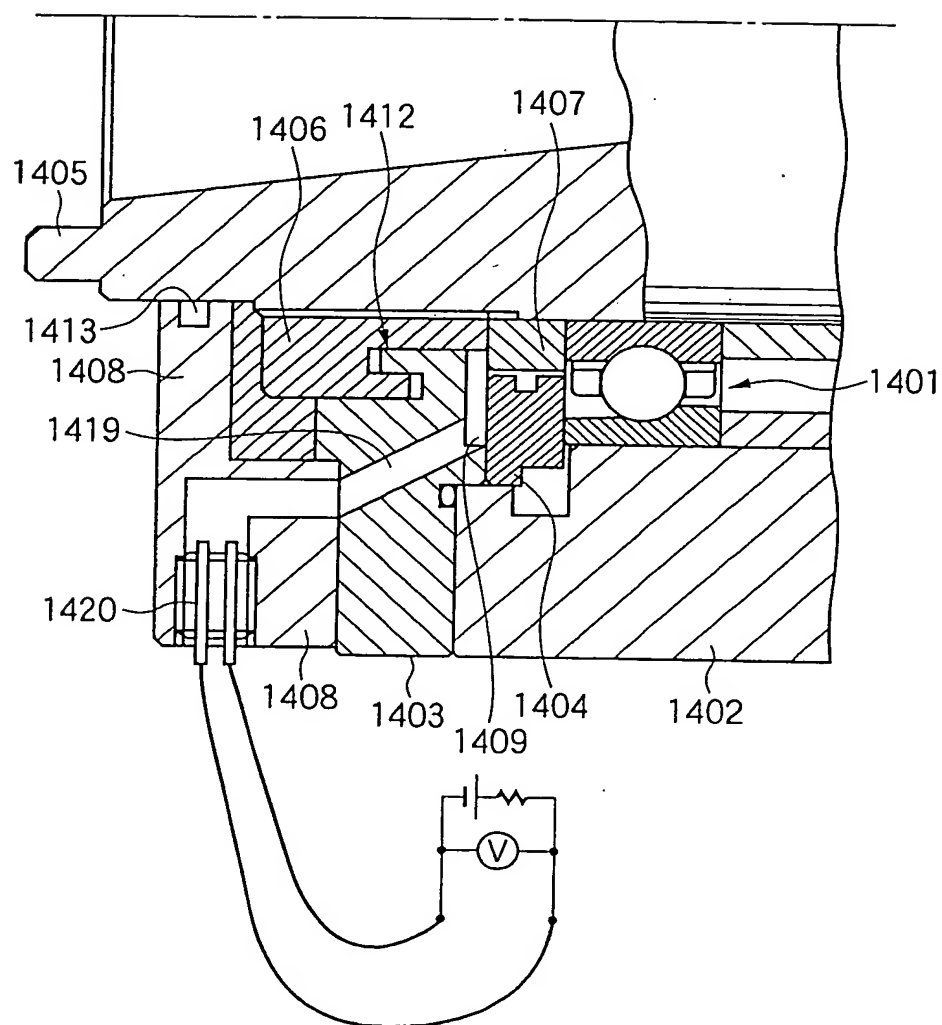


図 97

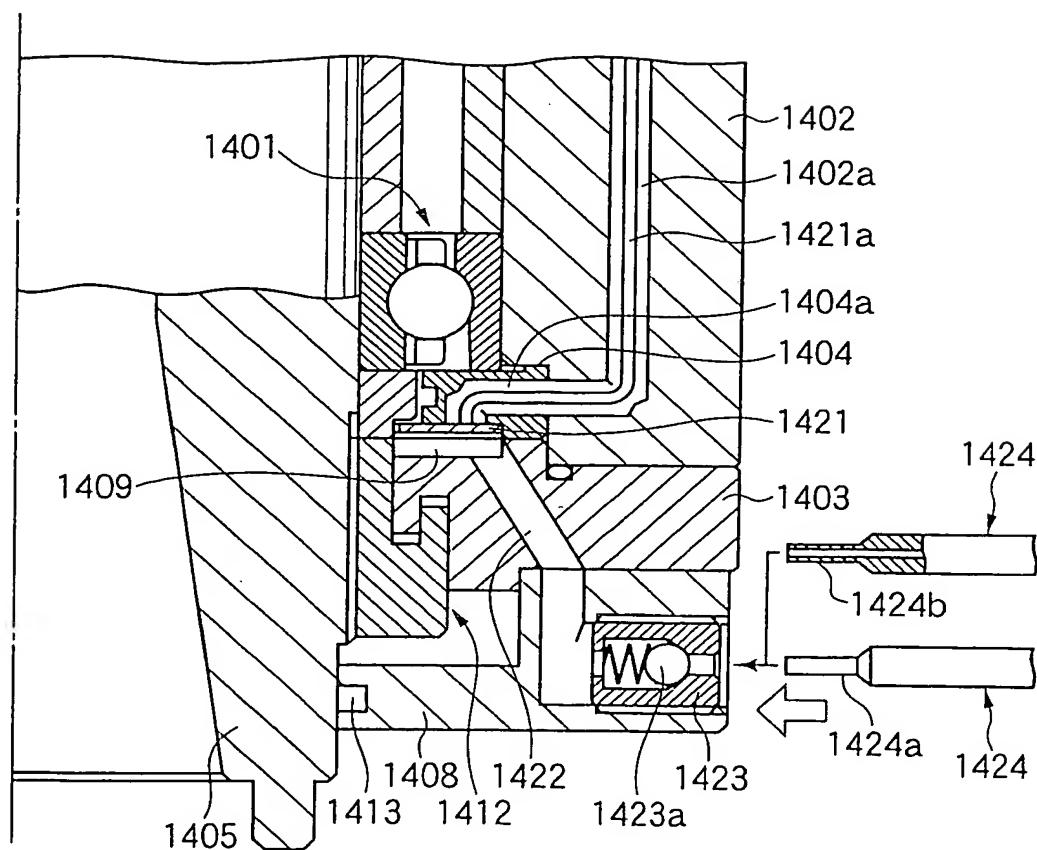


図 98

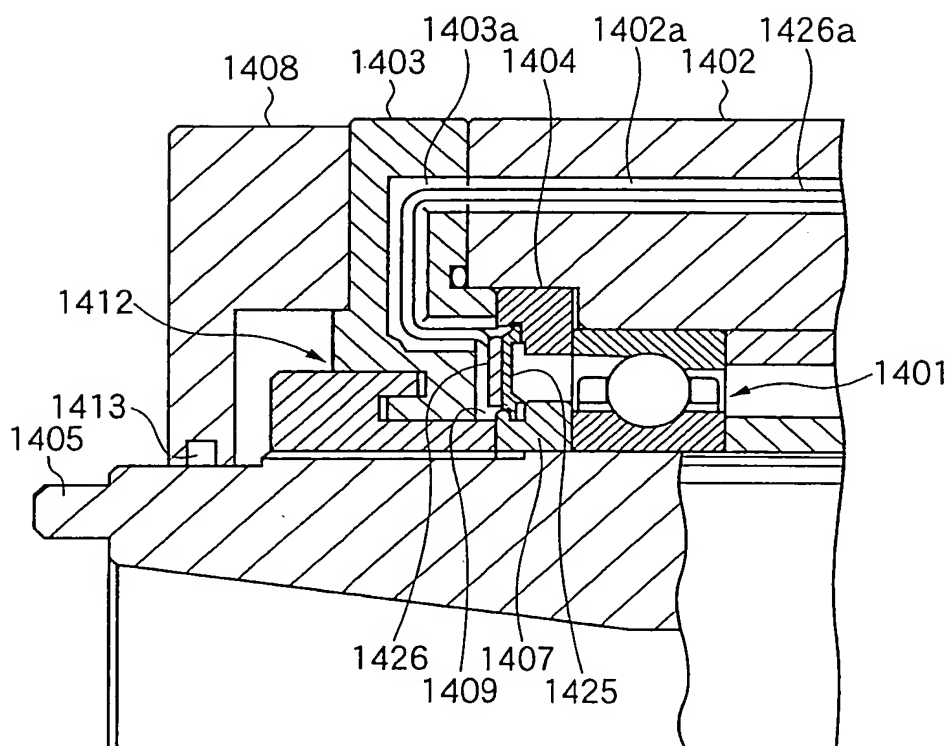


図 99

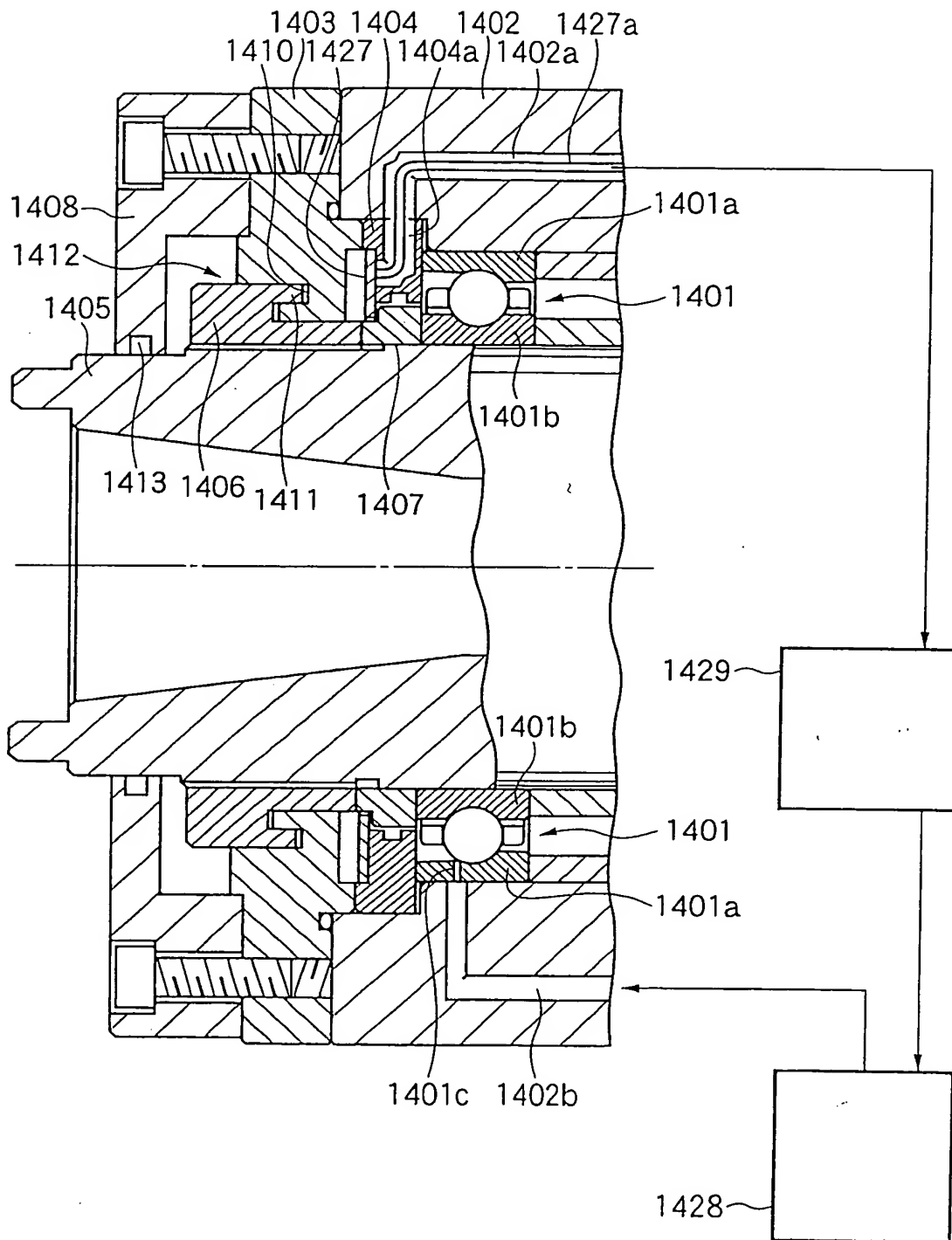


図 100

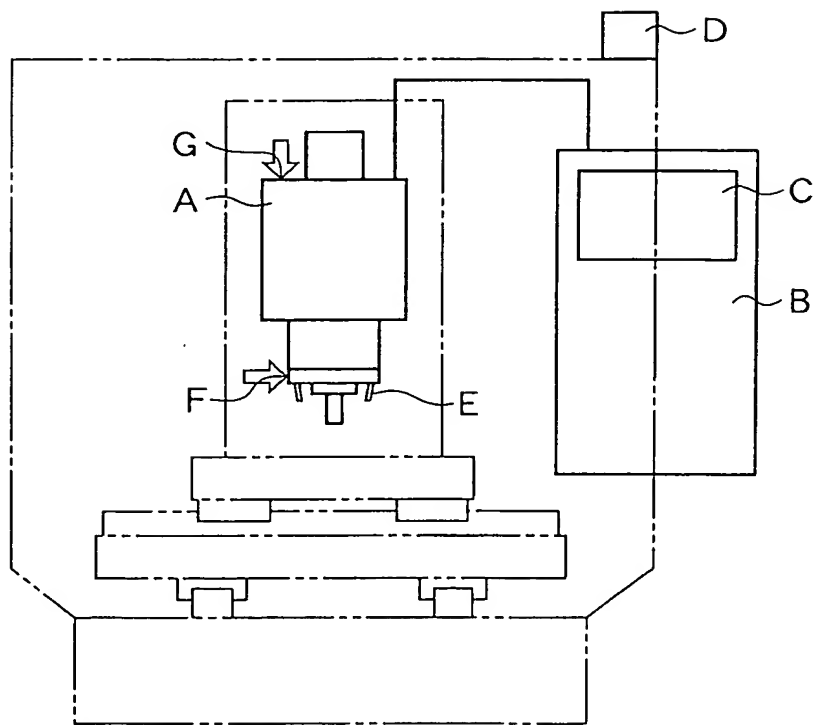


図 101

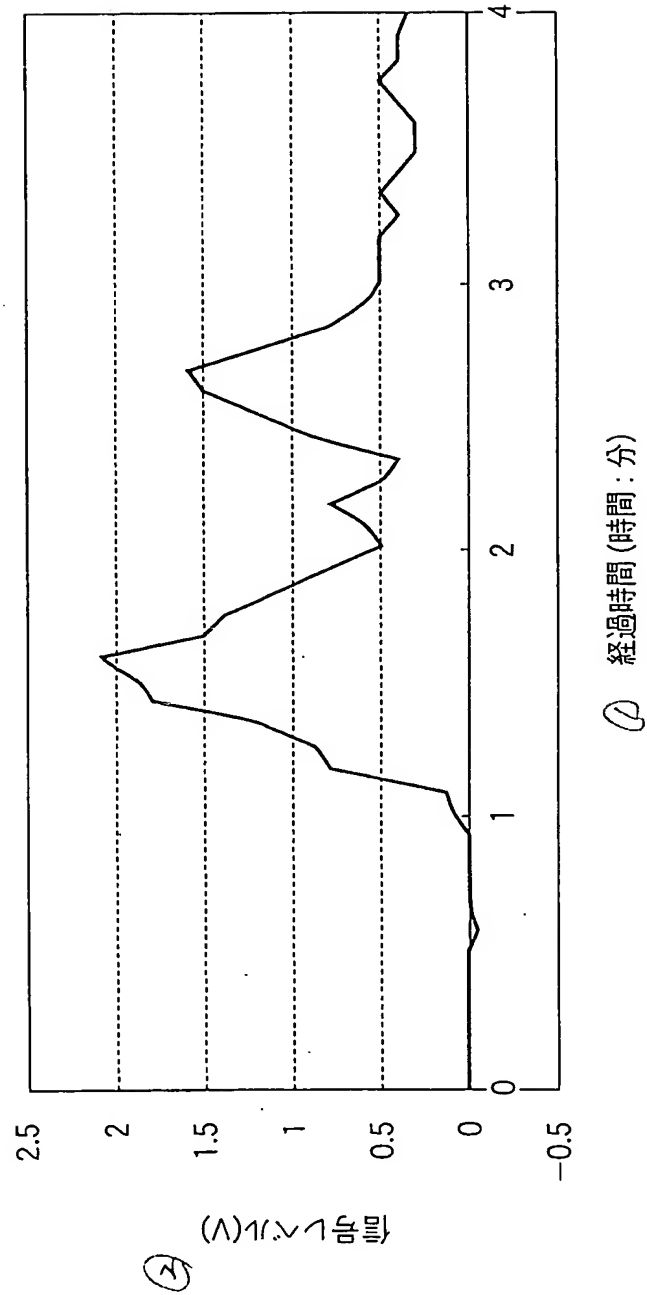


図 102

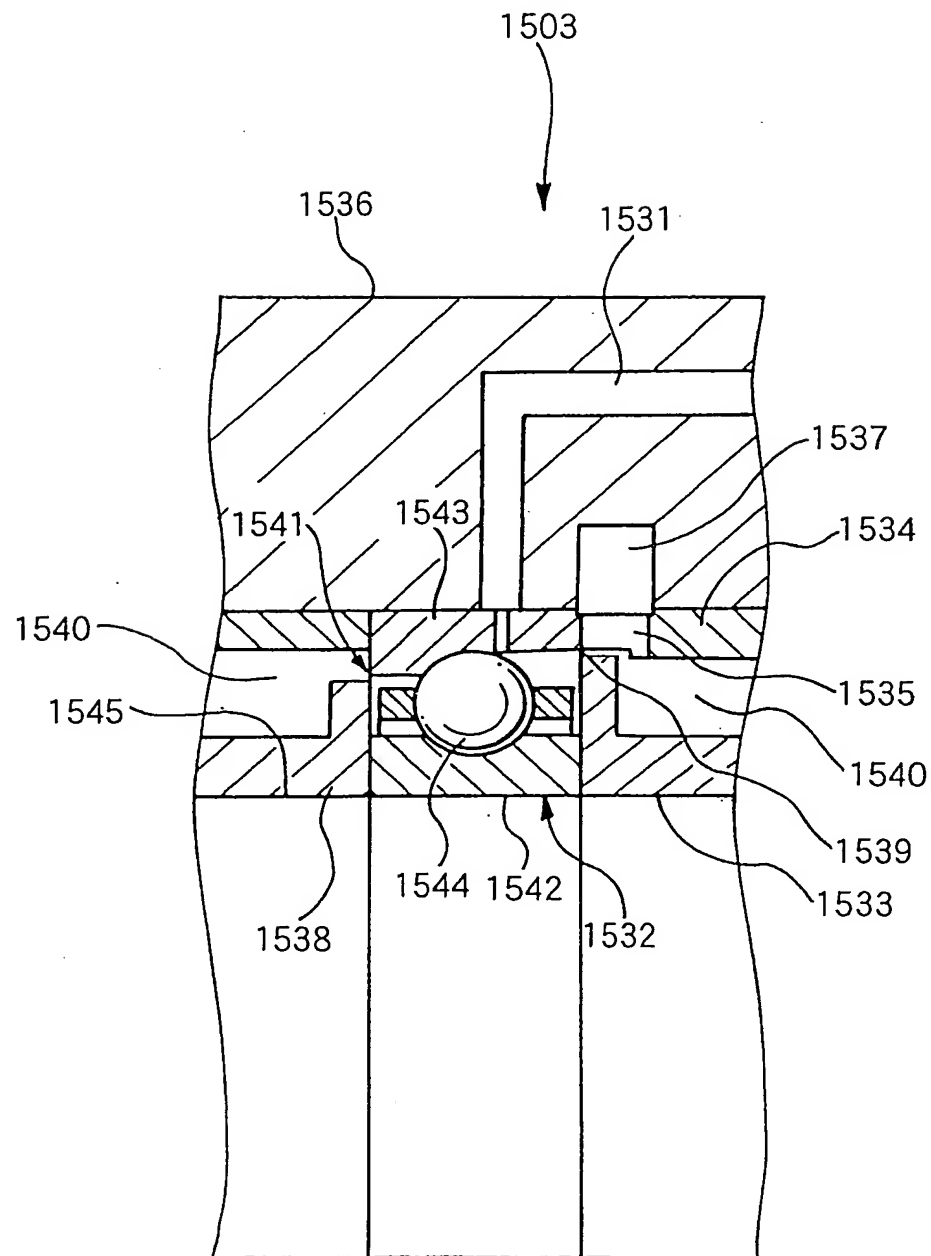
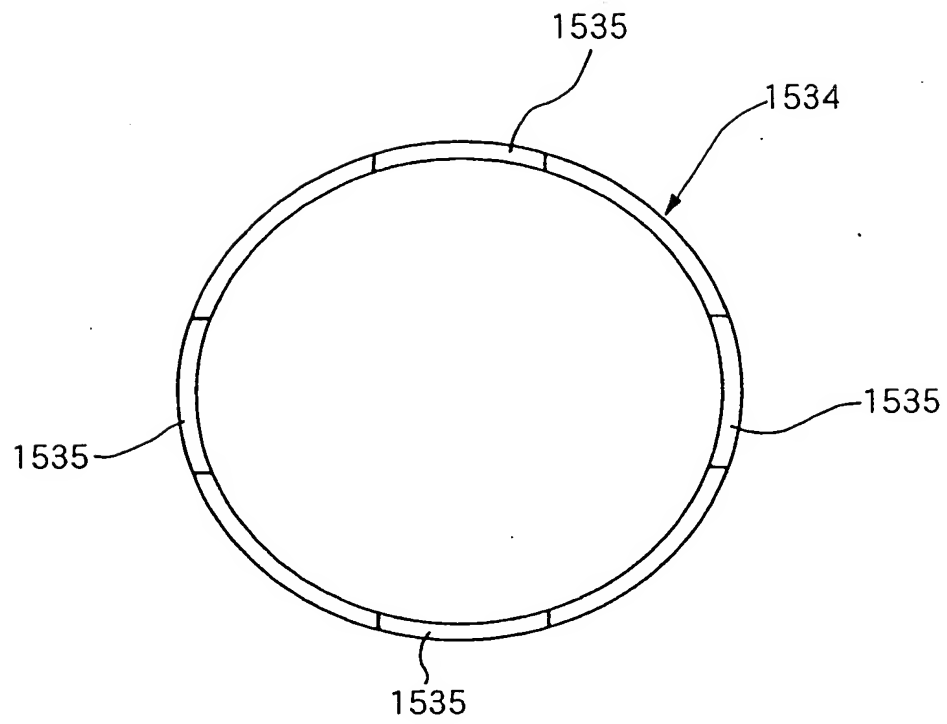


図 103

(a)



(b)

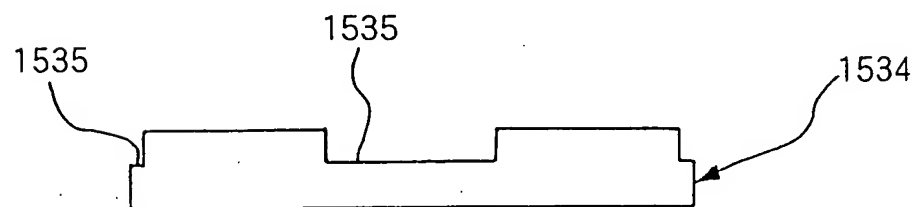


図 104

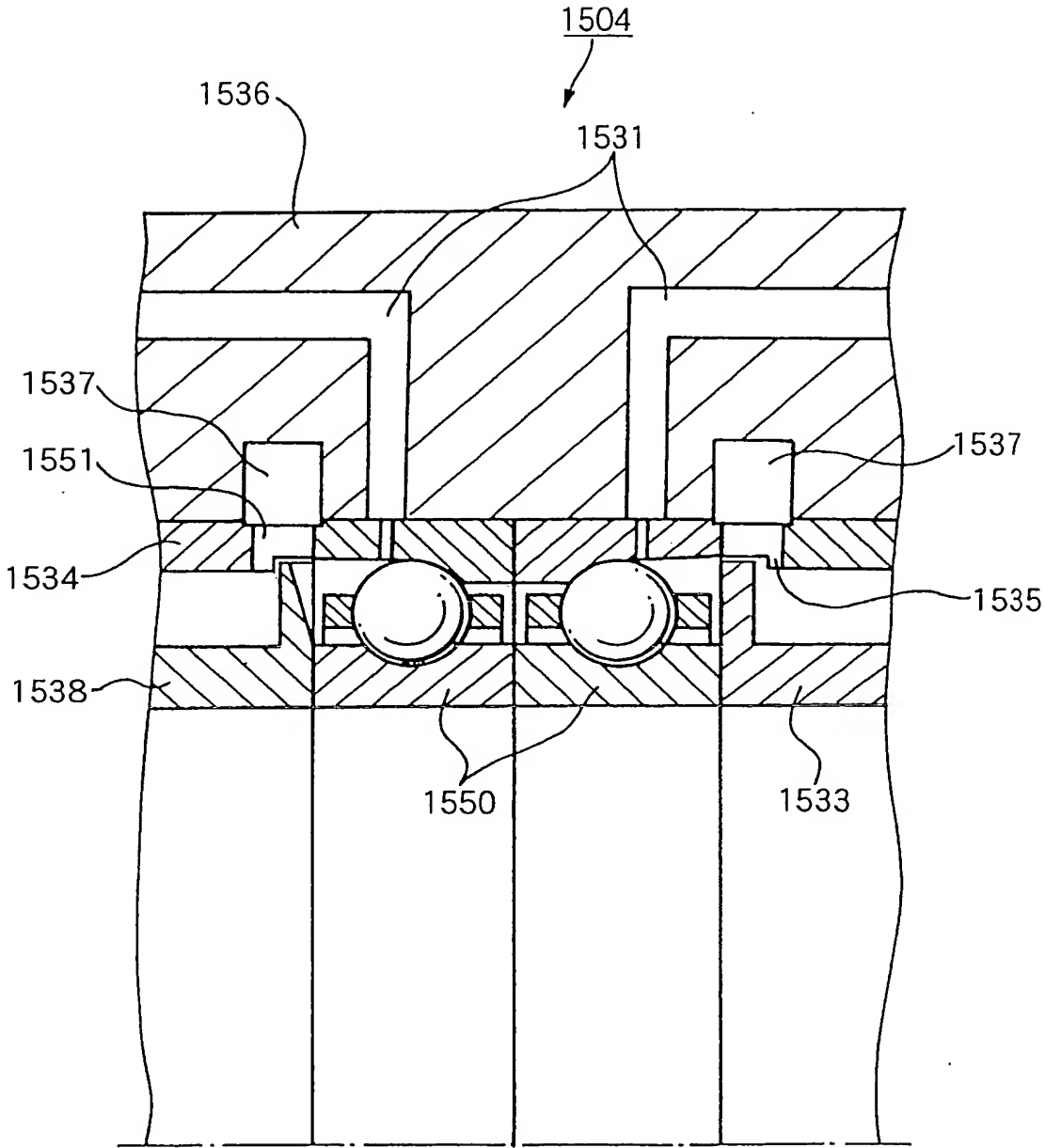
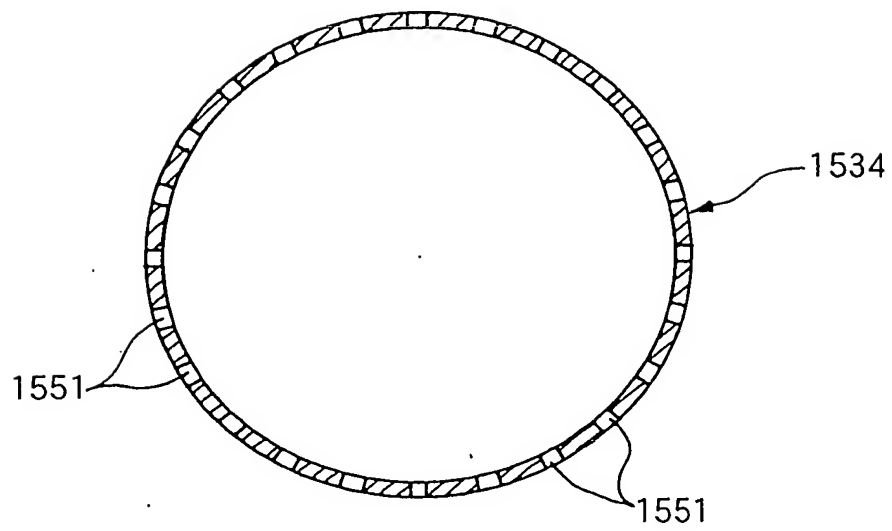


図 105

(a)



(b)

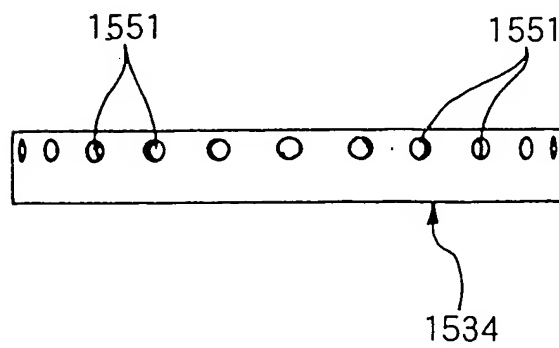


図 106

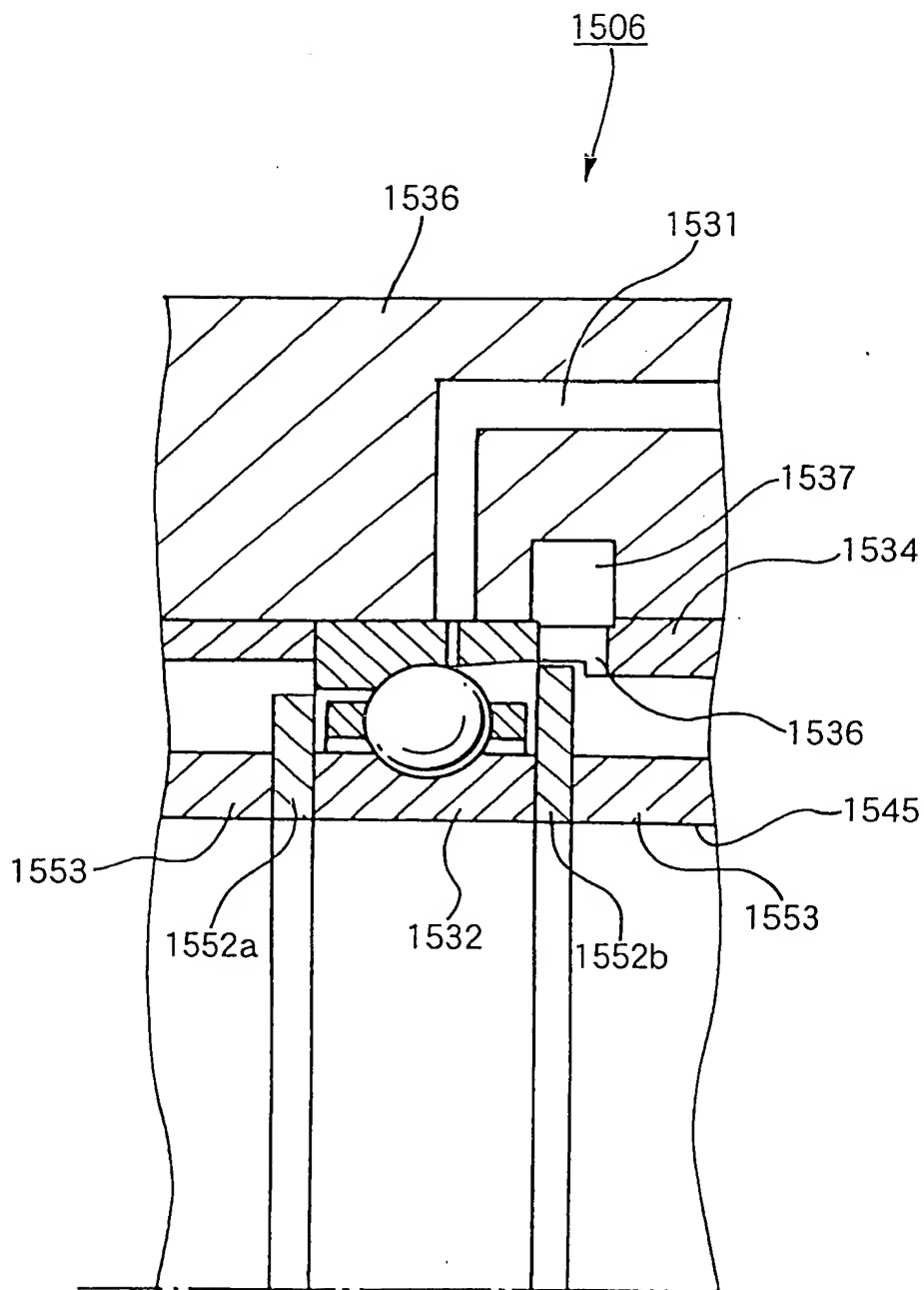


図 107

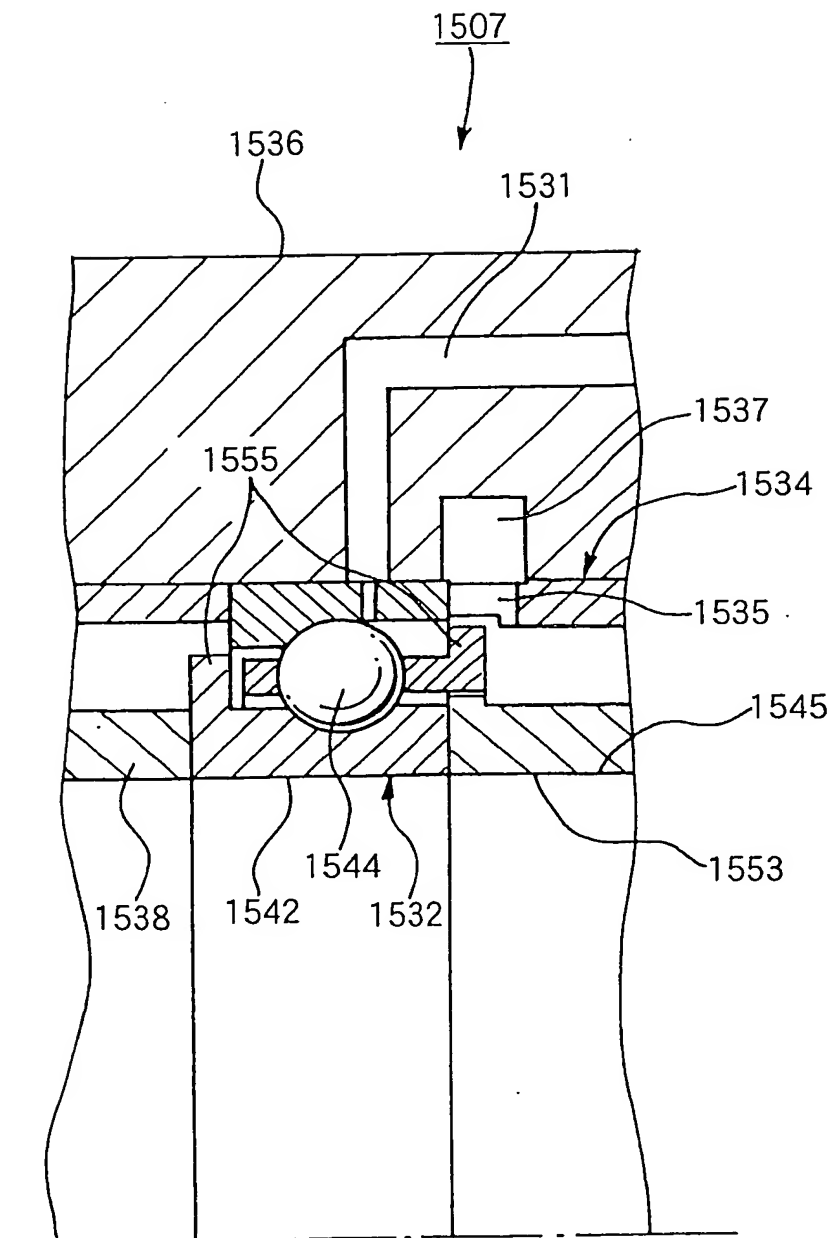


図 108

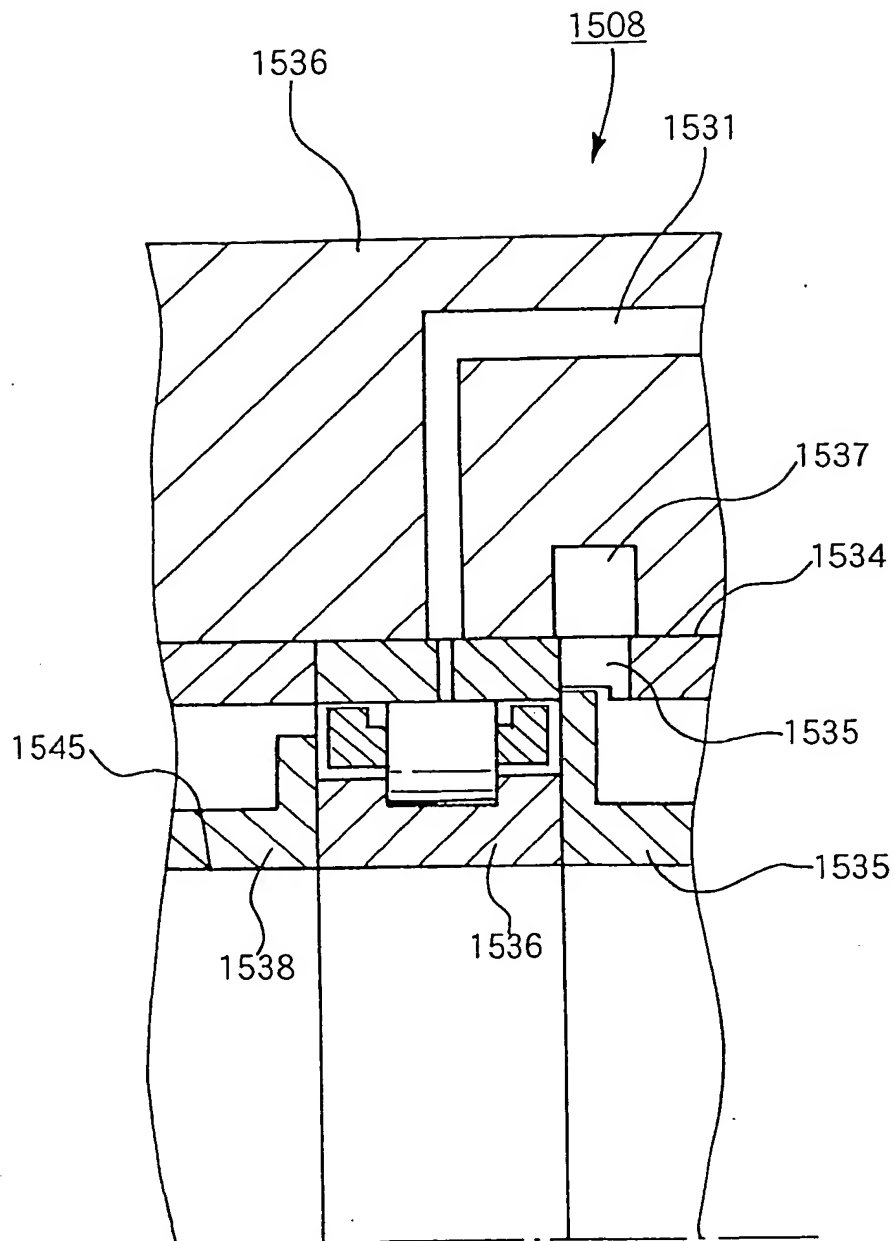


図 109

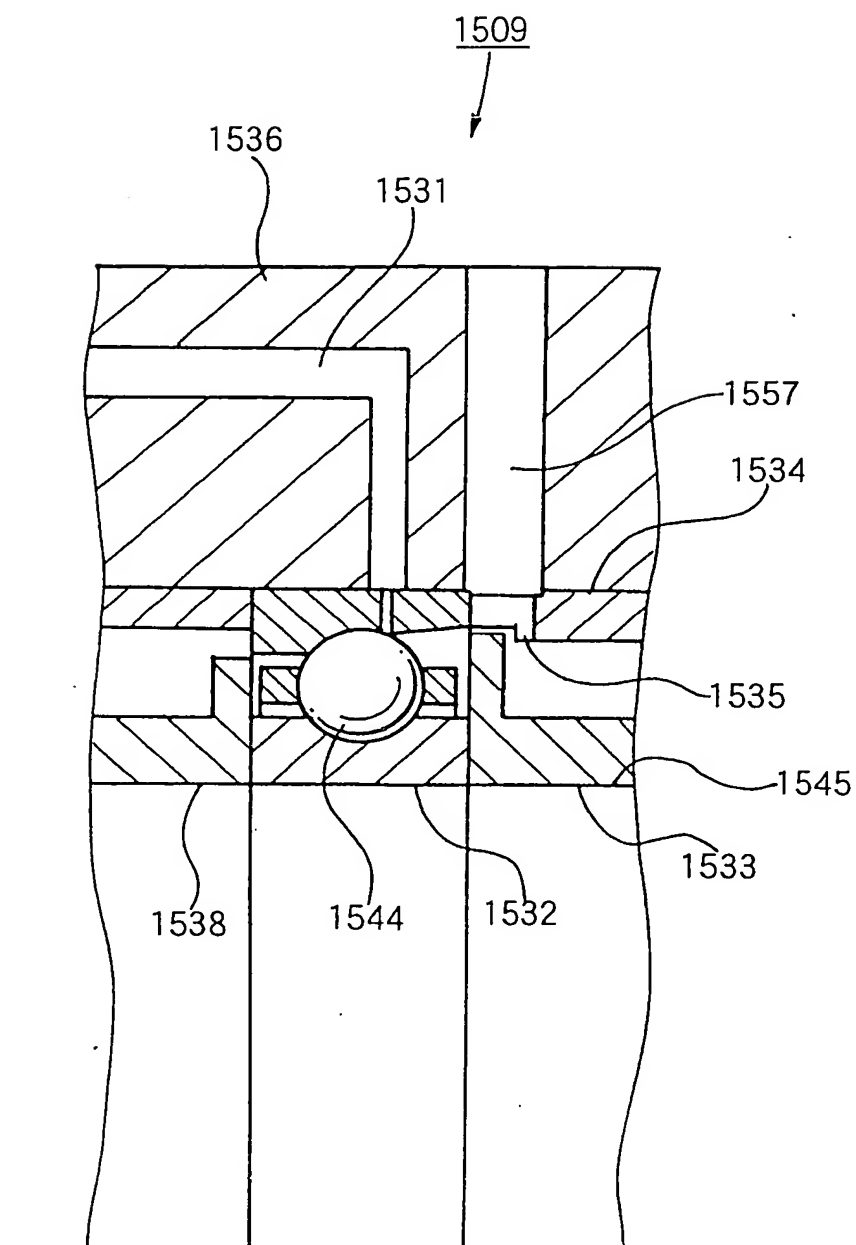


図 110

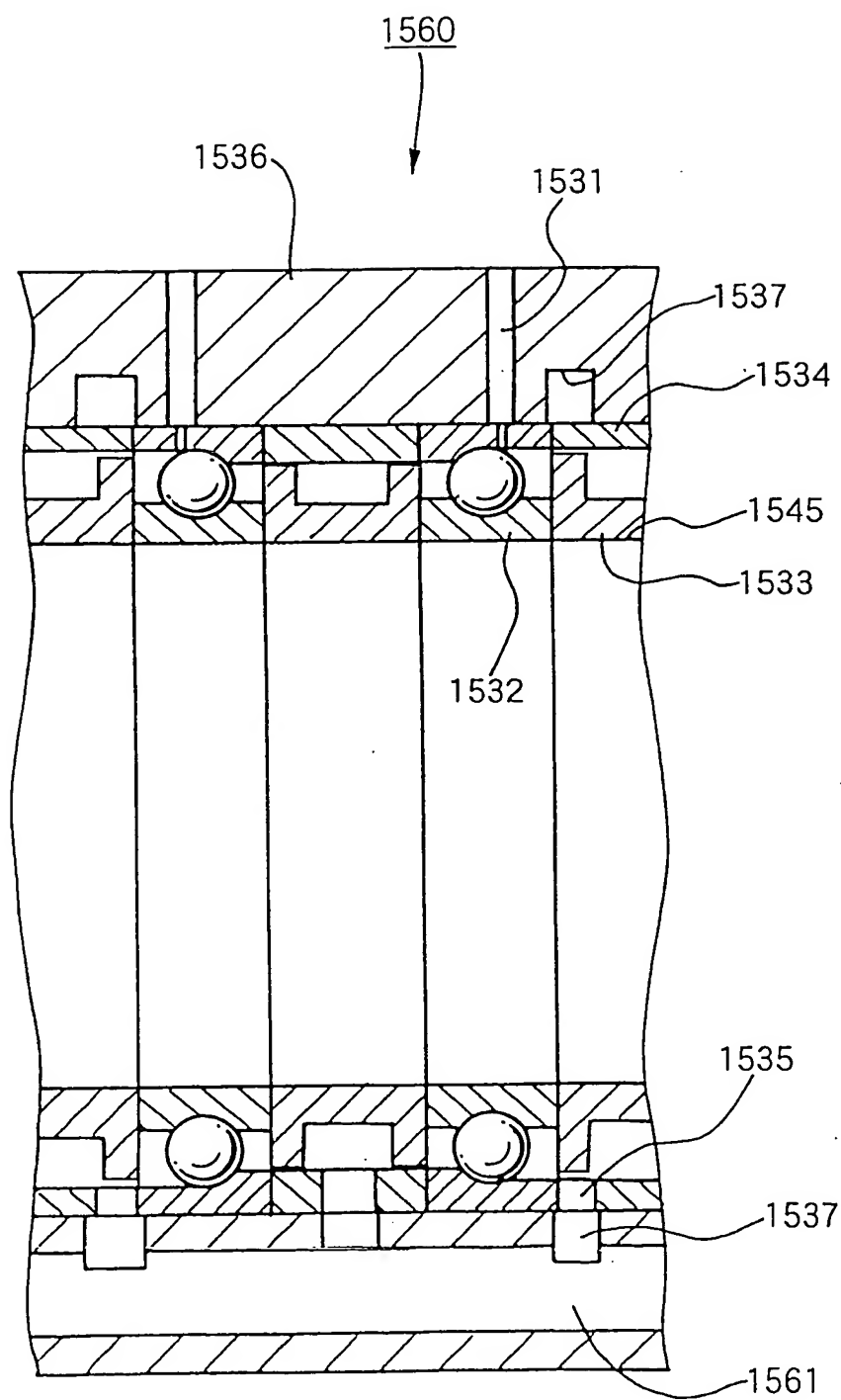


図 111

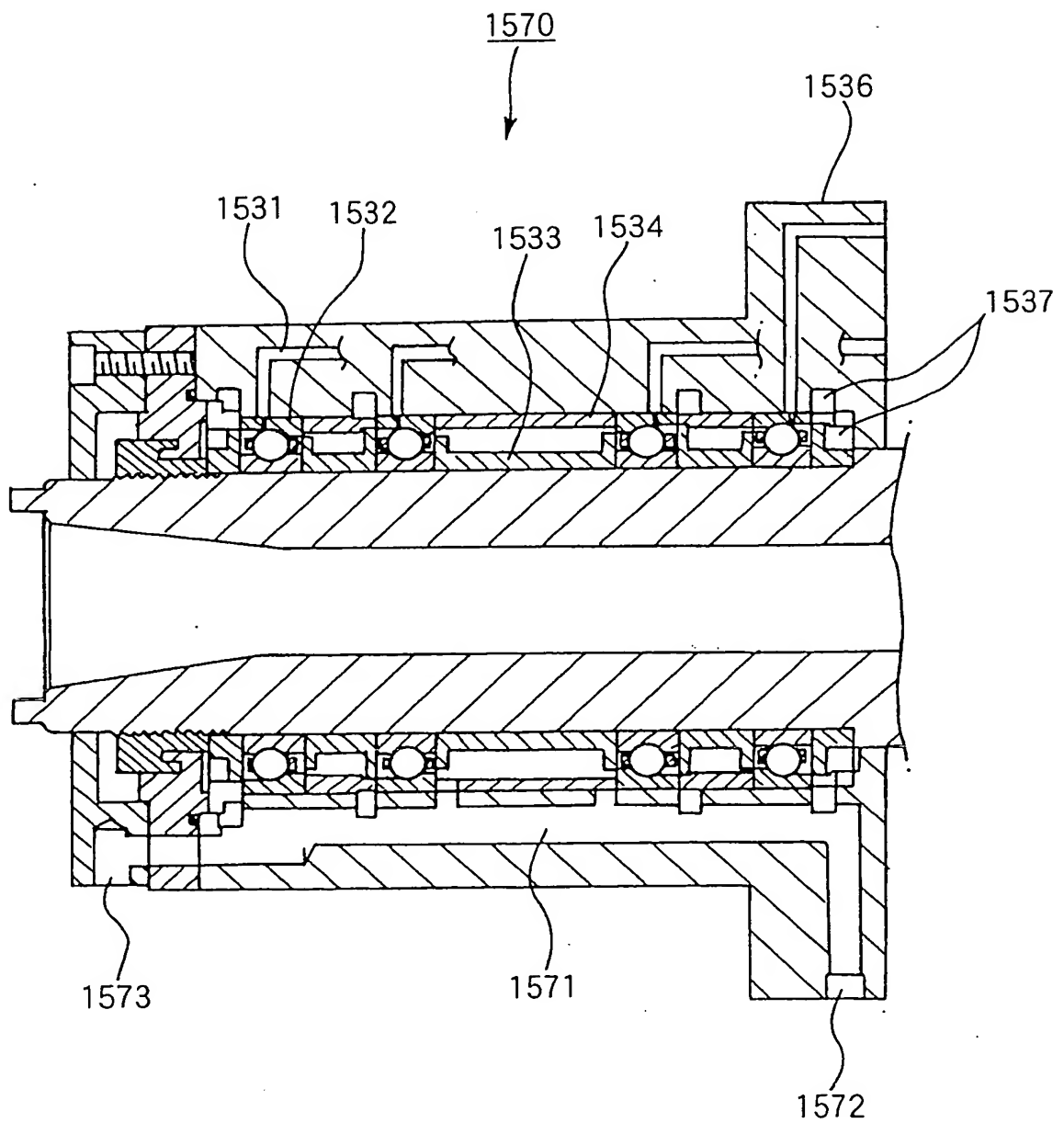


図 112

(a)

	① 従来	② 本発明
③ 連続運転時間	⑤ 45時間で異常昇温	⑥ 100時間後も異常昇温なし
④ 軸受内部 グリース残存量	⑦ 軸受空間容積の 70%残存	⑧ 軸受空間容積の 30~40%残存

(b)

① 試験条件

② 軸受内径	65mm
③ 主軸回転数	④ 20000回転/分
⑤ 試験時間	⑥ 100時間
⑦ 潤滑材	⑧ 潤滑材:グリース 初期封入量:軸受空間容積の15%
	⑨ 供給量:0.02cc/7.5分(軸受1個あたり)

図 113

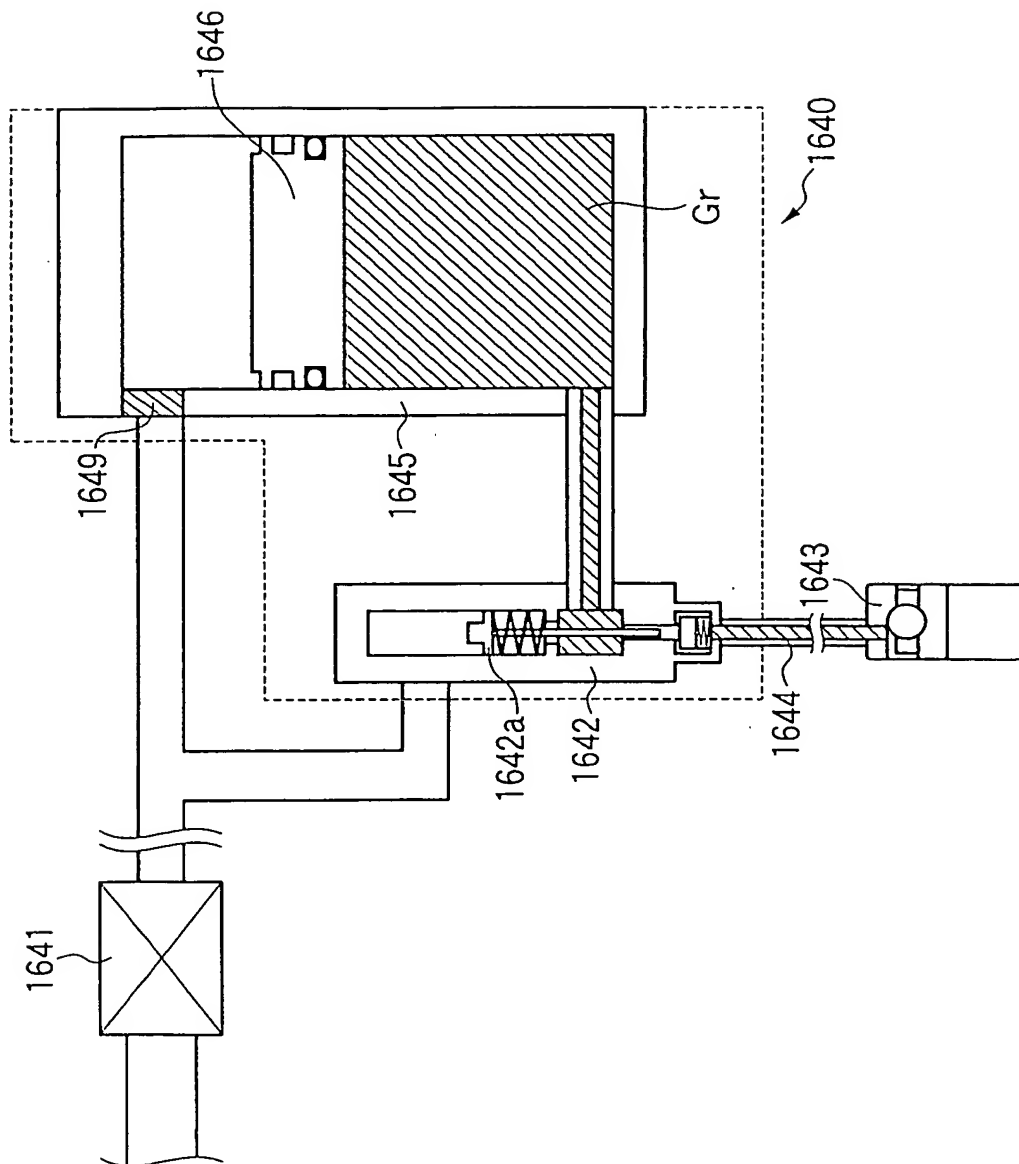


図 114

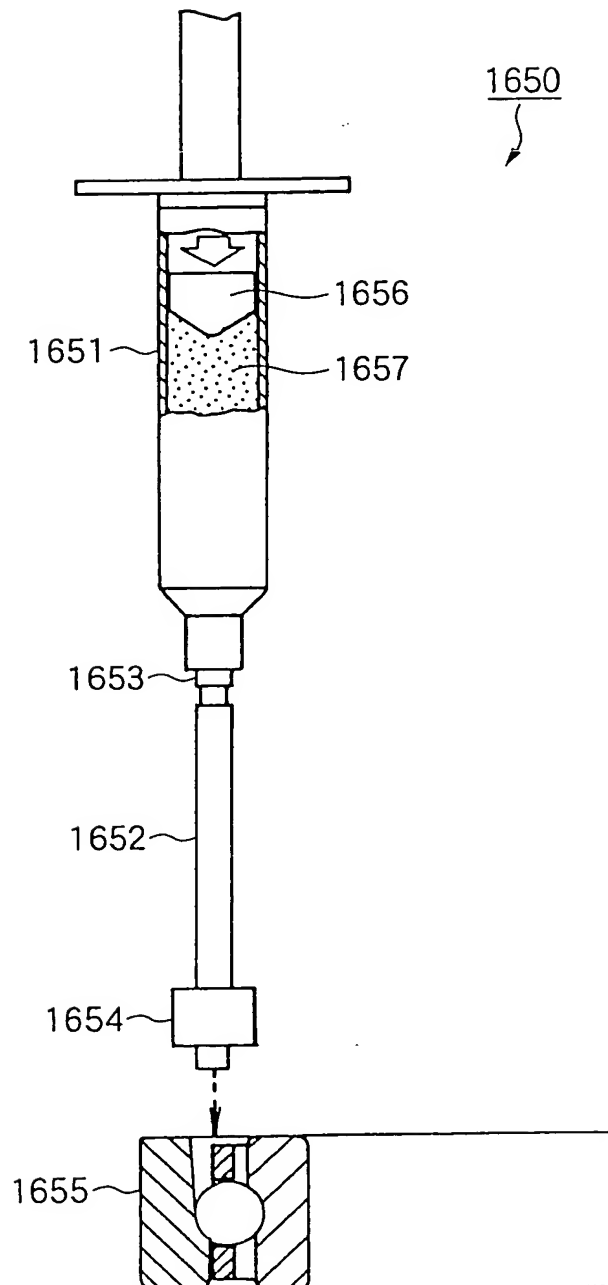


図 115

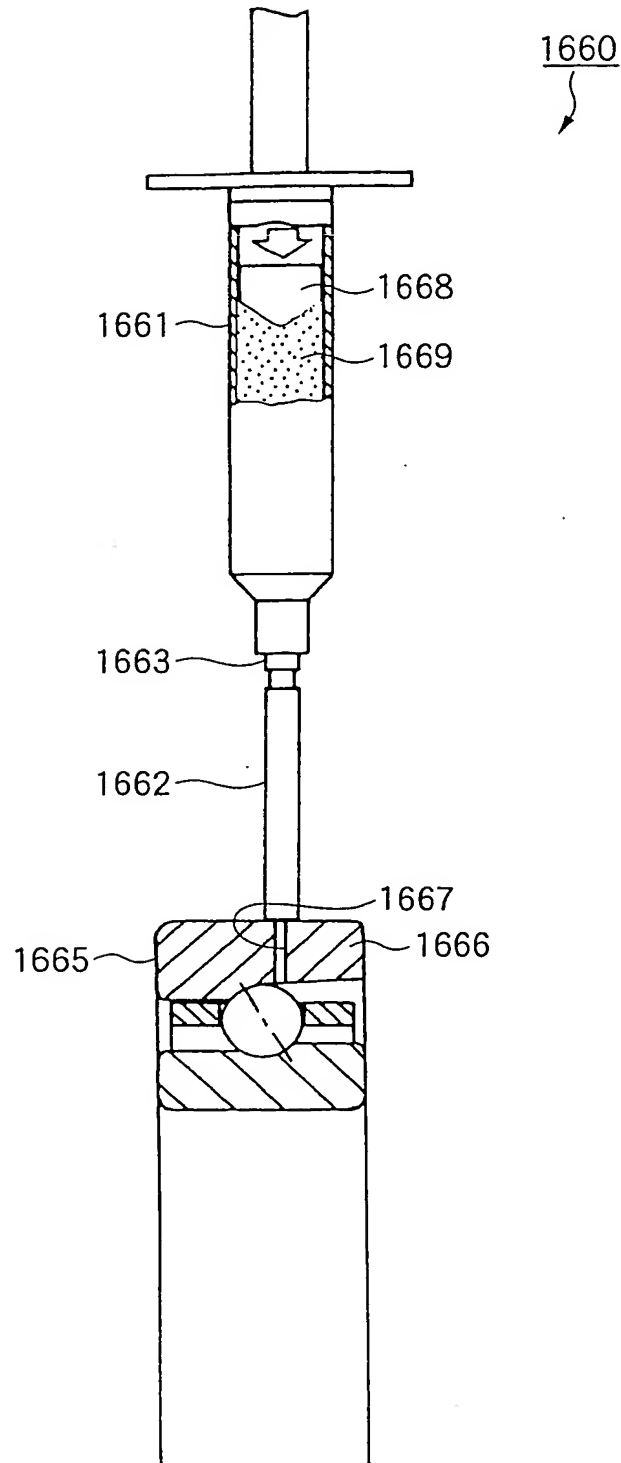


図 116

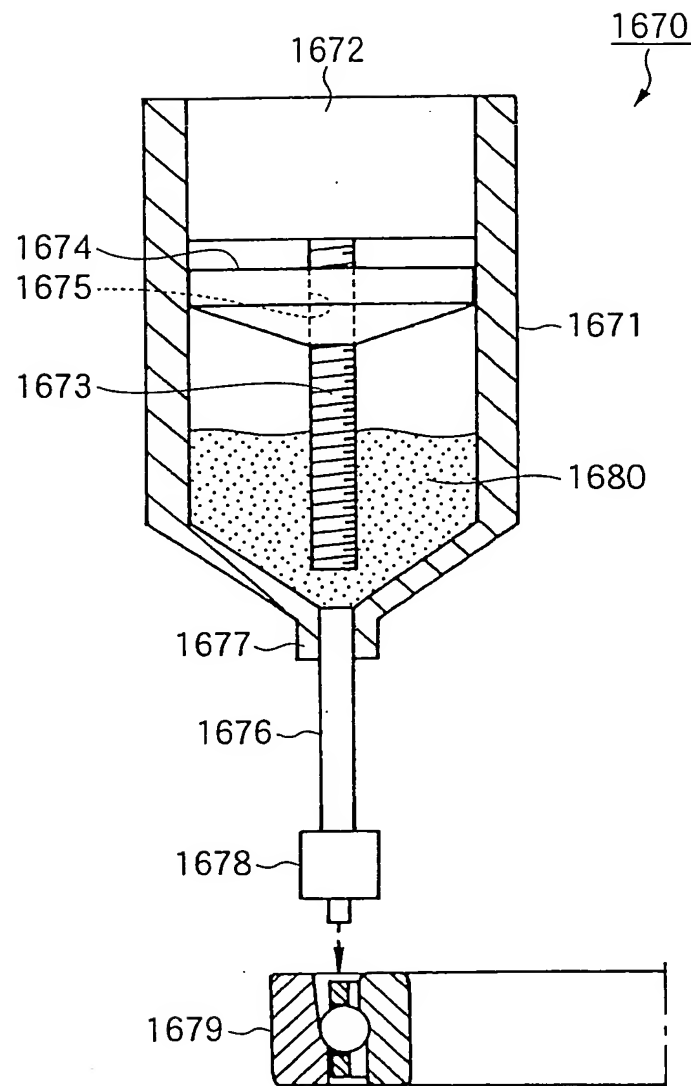
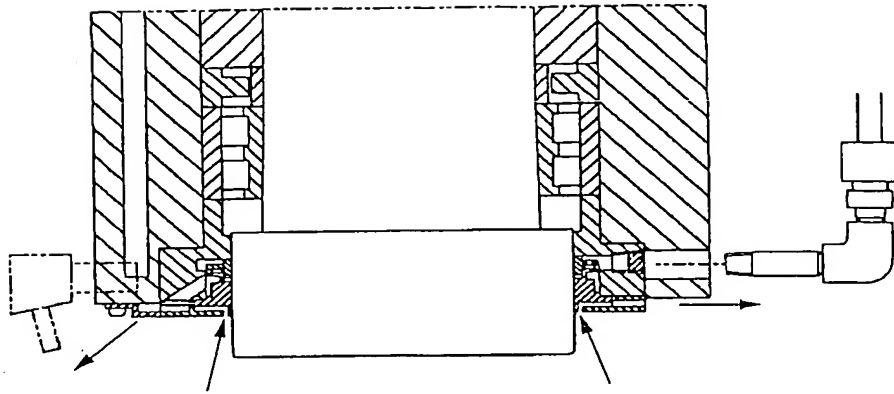
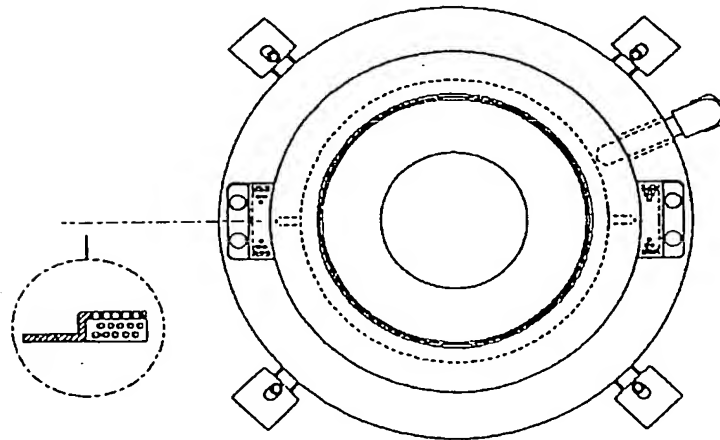


図 117

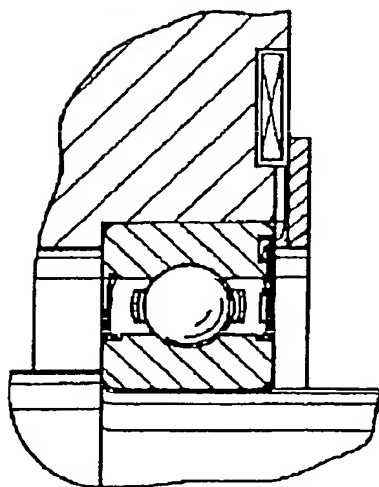


(a)

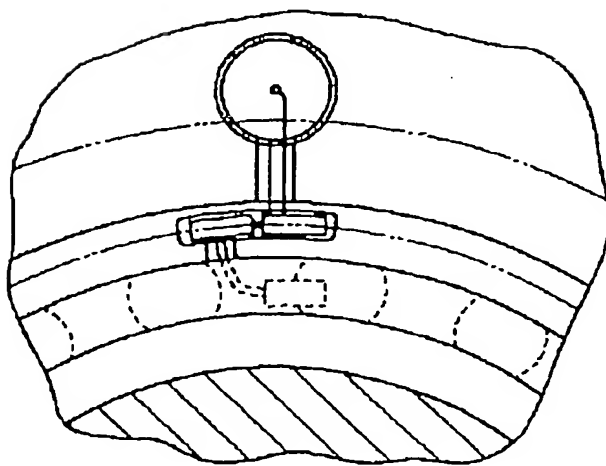


(b)

图 118



(a)



(b)

図 119

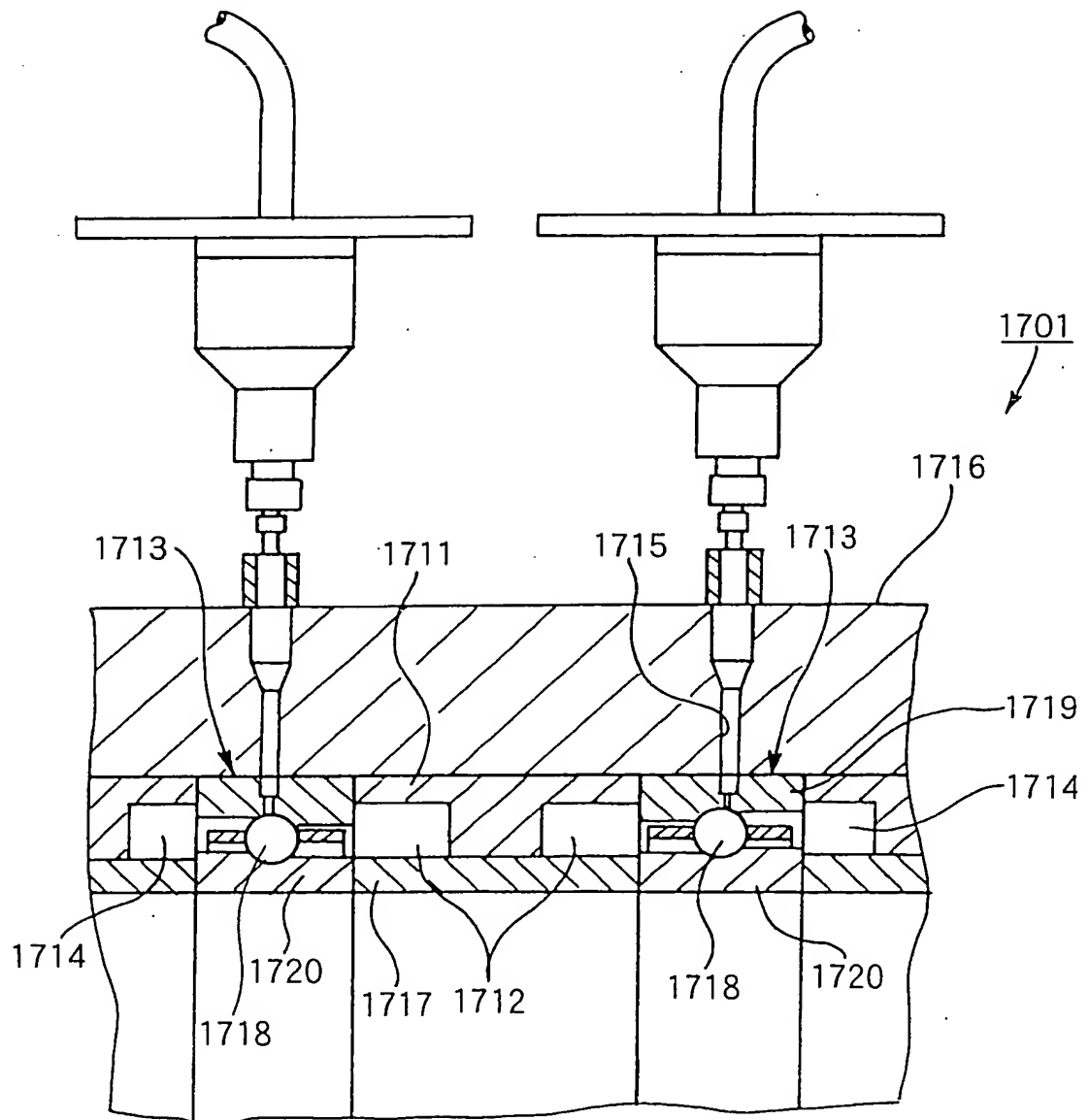


図 120

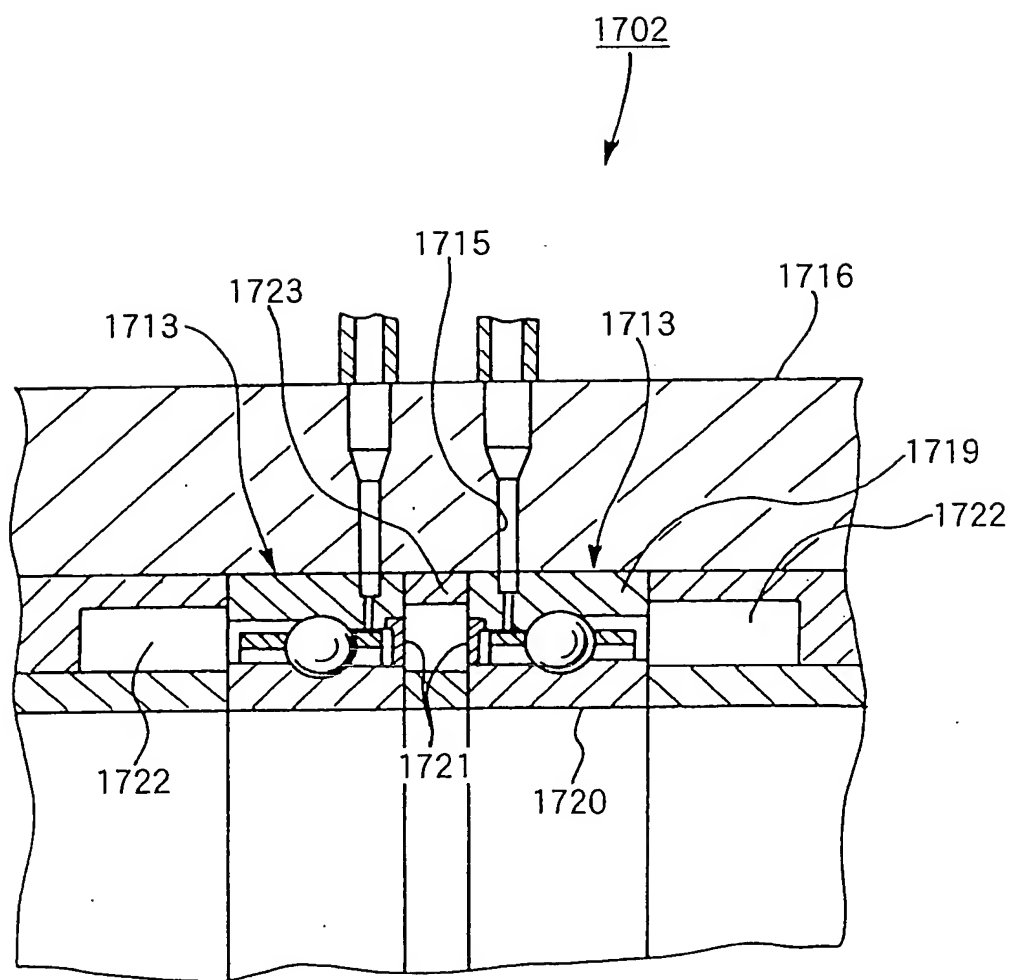


図 121

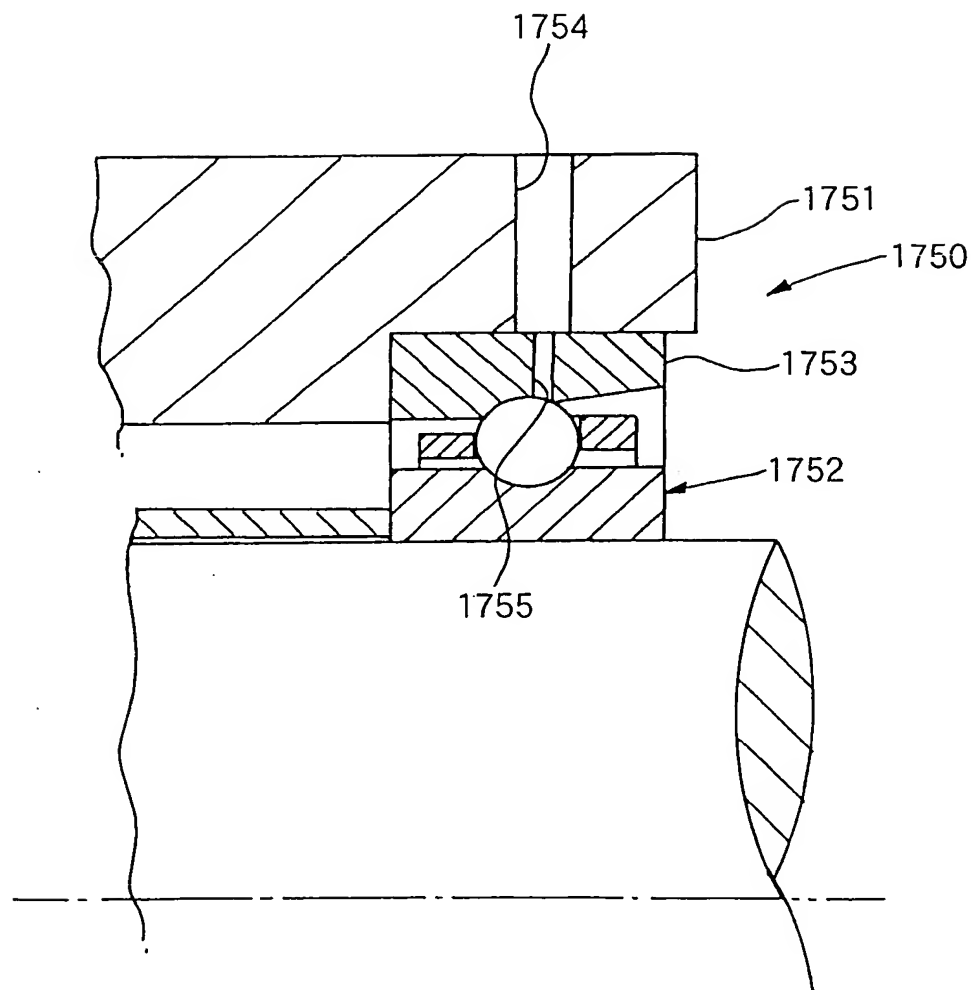


FIG.16:

- (1) grease supply unit 190

FIG.17:

- (1) grease supply unit 2

FIGS.26(a),(b),(c),(d),(e):

- (1) time elapsed
- (2) bearing temperature
- (3) (time)

FIGS.41, 48:

- (1) to a grease supply unit 610
- (2) to a compressor 740
- (3) to a control unit 620

FIG.42:

- (1) resistance-type grease supply unit 610
- (2) control unit 620
- (3) external device 630
- (4) rotation speed sensor 640
- (5) bearing unit 700 (800)
- (6) grease tank 720
- (7) grease feeding nozzle 722
- (8) solenoid valve 730
- (9) compressor 740

FIG.43:

- (1) grease feeding unit 610
- (2) control unit 620
- (3) pulse detector 622
- (4) external device 630
- (5) from a sensor

FIG.44:

- (1) start
- (2) read rotation speed data (S1)
- (3) Stopped ? (S2)
- (4) add 0 to the integrated value (S3)
- (5) Is the rotation speed low ? (S4)
- (6) add 1 to the integrated value (S5)
- (7) Is the rotation speed high ? (S6)
- (8) add 10 to the integrated value (S7)
- (9) Does the integrated value exceed 900000 ? (S8)

(10) output a grease feed command (S9)

(11) reset the value to 0 (S10)

FIG.45(a):

(1) rotation speed

(2) high speed

(3) low speed

(4) stop

(5) time

FIG.45(b):

(1) integrated value

(2) limited value

(3) time

FIG.45(c):

(1) supplying timing I

(2) supply

(3) time

FIG.45(d):

(1) supplying timing II

(2) supply

(3) time

FIG.46:

(1) start

(2) read the rotation speed data (S11)

(3) Stopped ? (S12)

(4) add 0 to the integrated value (S13)

(5) Is the rotation speed low ? (S14)

(6) add 0.1 to the integrated value (S15)

(7) Is the rotation speed middle ? (S16)

(8) add 1 to the integrated value (S17)

(9) Is the rotation speed high ? (S18)

(10) add 10 to the integrated value (S19)

(11) Does the integrated value exceed 900000 ? (S20)

(12) output the grease feed command (S21)

(13) reset the value to 0 (S22)

FIG.47(a):

(1) rotation speed

(2) high speed

(3) middle speed

(4) low speed

(5) stop

(6) time

FIG.47(b):

(1) integrated value

(2) limited value

(3) time

FIG.47(c):

(1) supplying timing I

(2) supply

(3) time

FIG.47(d):

(1) supplying timing II

(2) supply

(3) time

FIG.49:

(1) spindle unit 750

(2) solenoid valve 904

(3) air pressure sensor 905

(4) controller 906

(5) display device 907

(6) memory 908

(7) input device 909

(8) grease pressure sensor 911

(9) level sensor 912

(10) grease tank 913

(11) fixed-displacement discharge unit 914

(12) rotation speed sensor 921

FIG.50:

(1) grease supply unit 910

FIG.51:

(1) start

(2) read the rotation speed data (S31)

(3) integrating process (S32)

(4) Is the integrated value smaller than a predetermined value ? (S33)

(5) reset the integrated value (S34)

(6) open the solenoid valve (S35)

(7) check a pressure on the air source side (S36)

- (8) check a pressure on the grease supply unit side (S37)
- (9) check a level (S38)

FIG.52:

- (1) start of the integrating process
- (2) Does the rotation speed belong to a low speed area (S41)
- (3) add 1 to the integrated value (S42)
- (4) Does the rotation speed belong to a middle speed area (S43)
- (5) add 2 to the integrated value (S44)
- (6) add 10 to the integrated value (S45)
- (7) end of the integrating process

FIG.53:

- (1) start of air pressure checking
- (2) The air pressure sensor ON ? (S51)
- (3) reset the OFF number of times of the air pressure sensor to 0 (S52)
- (4) end of air pressure checking
- (5) the OFF number of times of the air pressure sensor + 1 (S53)
- (6) The OFF number of times of the air pressure sensor = 3 ? (S54)
- (7) to step S35
- (8) display an alarm 1 (S55)
- (9) limit the number of rotation of the spindle (S56)
- (10) The restart button ON ? (S57)
- (11) reset the display of the alarm 1 (S58)
- (12) reset the OFF number of times of the air pressure sensor to 0 (S59)
- (13) release the limit(S60)

FIG.54:

- (1) start of grease pressure check
- (2) The grease pressure sensor ON ? (S61)
- (3) display an alarm 2 (S62)
- (4) limit the number of rotation of the spindle (S63)
- (5) The alarm release button ON ? (S64)
- (6) reset alarm 2, 3, 4 displays (S65)
- (7) reset the grease shot number of times counter to 0 (S66)
- (8) release the limit (S67)
- (9) end of grease pressure check

FIG.55:

- (1) start of level check
- (2) The level sensor ON ? (S71)
- (3) display an alarm 3 (S72)

- (4) the grease shot number of times + 1 (S73)
- (5) Is the shot number of times smaller than 30 ? (S74)
- (6) display an alarm 4 (S75)
- (7) change the number of rotation of the shaft into 15000 min^{-1} (S76)
- (8) to step S64
- (9) end of level check

FIG.59:

- (1) grease supply system 1010
- (2) solenoid valve 1012
- (3) level sensor 1018a
- (4) grease pressure sensor 1018b
- (5) air source 1020
- (6) air pressure sensor 1023
- (7) spindle unit 1024
- (8) rotation speed sensor 1024a
- (9) sequence controller 1030

FIG.60:

- (1) name
- (2) operation timing and monitoring time
- (3) operation
- (4) contents
- (5) solenoid valve
- (6) air pressure sensor
- (7) grease pressure sensor
- (8) level sensor
- (9) reduction of the air pressure
- (10) reduction of the grease tank pressure
- (11) lack of a residual amount in the grease tank

FIG.62:

- (1) grease supply system 1010
- (2) first solenoid valve 1012
- (3) level sensor 1018a
- (4) grease pressure sensor 1018b
- (5) air source 1020
- (6) air pressure sensor 1023
- (7) spindle unit 1024
- (8) rotation speed sensor 1024a
- (9) second solenoid valve 1029

(10) sequence controller 1030

FIG.63:

- (1) name
- (2) operation timing and monitoring time
- (3) operation
- (4) contents
- (5) second solenoid valve
- (6) first solenoid valve
- (7) air pressure sensor
- (8) grease pressure sensor
- (9) level sensor
- (10) reduction of the air pressure
- (11) reduction of the grease tank pressure
- (12) lack of a residual amount in the grease tank

FIG.64:

- (1) grease supply system 1010
- (2) first solenoid valve 1012
- (3) level sensor 1018a
- (4) grease pressure sensor 1018b
- (5) air source 1020
- (6) first air pressure sensor 1023
- (7) spindle unit 1024
- (8) rotation speed sensor 1024a
- (9) second air pressure sensor 1026
- (10) second solenoid valve 1029
- (11) sequence controller 1030

FIG.65:

- (1) name
- (2) operation timing and monitoring time
- (3) operation
- (4) contents
- (5) second solenoid valve
- (6) first solenoid valve
- (7) first air pressure sensor
- (8) second air pressure sensor
- (9) grease pressure sensor
- (10) level sensor
- (11) reduction of the air pressure

- (12) reduction of the grease tank pressure
- (13) lack of a residual amount in the grease tank

FIG.66:

- (1) time (min)
- (2) pressure in the tank (MPa)
- (3) solenoid valve [ON]
- (4) solenoid valve [OFF]
- (5) pressure at which an operation of a grease pressure switch is started
- (6) grease residual amount: full
- (7) grease residual amount: none

FIG.77:

- (1) spindle unit 1210
- (2) grease supply system 1217
- (3) cooling fluid supply source 1218
- (4) rotary joint 1232
- (5) clean air supply source 1245
- (6) supply system driving air supply
- (7) grease supply
- (8) housing cooling fluid supply
- (9) spindle cooling fluid supply
- (10) housing cooling fluid recovery
- (11) spindle cooling fluid recovery
- (12) supplied every bearing
- (13) clean air supply

FIG.78:

- (1) cooling fluid supply source 1218
- (2) housing cooling fluid supply

FIG.79:

- (1) spindle unit 1210
- (2) grease supply system 1217
- (3) cooling fluid supply source 1 1218a
- (4) cooling fluid supply source 2 1218b
- (5) rotary joint 1232
- (6) clean air supply source 1245
- (7) supply system driving air supply
- (8) grease supply
- (9) housing cooling fluid supply
- (10) spindle cooling fluid supply

- (11) housing cooling fluid recovery
- (12) spindle cooling fluid recovery
- (13) supplied every bearing
- (14) clean air supply

FIG.80:

- (1) spindle unit 1210
- (2) grease supply system 1217
- (3) cooling fluid supply source 1218
- (4) rotary joint 1232
- (5) clean air supply source 1245
- (6) supply system driving air supply
- (7) grease supply
- (8) cooling fluid supply
- (9) cooling fluid recovery
- (10) supplied every bearing
- (11) clean air supply

FIG.81:

- (1) spindle unit 1210
- (2) grease supply system 1217
- (3) cooling fluid supply source 1218
- (4) rotary joint 1232
- (5) grease supply
- (6) housing cooling fluid supply
- (7) spindle cooling fluid supply
- (8) housing cooling fluid recovery
- (9) spindle cooling fluid recovery
- (10) supplied every bearing

FIG.82:

- (1) spindle unit 1210
- (2) grease supply system 1217
- (3) cooling fluid supply source 1 1218a
- (4) cooling fluid supply source 2 1218b
- (5) rotary joint 1232
- (6) grease supply
- (7) housing cooling fluid supply
- (8) spindle cooling fluid supply
- (9) housing cooling fluid recovery
- (10) spindle cooling fluid recovery

(11) supplied every bearing

FIG.83:

(1) grease supply system 1390

FIGS.85, 89:

(1) test No.

(2) constant preload (N)

(3) amount initially sealed of grease (%)

(4) amount initially sealed of grease (cc)

(5) cooling (cooling oil temperature)

(6) bearing temperature (°C)

(7) endurance time (hr)

(8) applied (25 °C)

FIG.86:

(1) Amount sealed of grease-Endurance time

(2) amount initially sealed of grease (%)

(3) running time at 22000 min^{-1} (hr)

FIG.87:

(1) test No.

(2) constant preload (N)

(3) amount initially sealed of grease (%)

(4) amount initially sealed of grease (cc)

(5) cooling (cooling oil temperature)

(6) bearing temperature (°C)

(7) endurance time (hr)

(8) applied (25 °C)

(9) applied (20 °C)

(10) not applied

FIG.88:

(1) Bearing temperature-Endurance time

(2) running time at 22000 min^{-1} (hr)

(3) temperature of the outer ring of the bearing in running (°C)

FIG.90:

(1) Preload-Endurance time

(2) running time at 22000 min^{-1} (hr)

(3) preload in running (N)

FIG.101:

(1) time elapsed (time: min)

(2) signal level (V)

FIG. 112(a):

- (1) prior art
- (2) present invention
- (3) continuous operation time
- (4) a residual amount of the grease in the bearing
- (5) abnormal temperature rise in 45 hour
- (6) no abnormal temperature rise after 100 hour
- (7) remained by 70 % of the bearing space volume
- (8) remained by 30 to 40 % of the bearing space volume

FIG.112(b):

- (1) test conditions
- (2) inner diameter of the bearing
- (3) the number of rotation of the spindle
- (4) 20000 rpm
- (5) test time
- (6) 100 hour
- (7) lubricant
- (8) lubricant: grease initially sealed amount: 15 % of the bearing space
 volume
- (9) supply amount: 0.02 cc/7.5 min (per bearing)